Learning to Breathe: The History of Newborn Resuscitation, 1929 to 1970.

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Abstract

The history of newborn resuscitation in the twentieth century presented thus far in the writings of practitioner-historians describes a ‘hands-off’ attitude to newborn care prior to the 1950s. These practioner-historians tend to recount a positivist narrative with the rapid expansion of newborn care after WWII and the eventual logical uptake of endotracheal intubation and positive pressure resuscitation as the most effective method for treating asphyxia neonatorum.

This thesis challenges this positivist narrative my examining the resuscitation of the newborn in Britain and America during the interwar period through to the late 1960s. It uncovers a much more complex and non-linear narrative for the development of newborn resuscitation during the twentieth century, uncovering some interesting themes which the practitioner-histories have not addressed. These themes include the interactions between neonatal and fetal physiologists and their research with clinicians and clinical practice, and the role of new groups of clinicians, the paediatricians and anaesthetists, in newborn resuscitation during this period.

Many of the practitioner-histories ridicule what they deem to be ‘failed’ resuscitation techniques, seeing them as ‘deveiations’ from the eventual widespread adoption of positive pressure methods. My analysis of both the clinical and scientific debates surrounding both the use of positive pressure methods and some of these ‘failed’ techniques provides a more complex and detailed story. Two techniques in particular, intragastric oxygen and hyperbaric oxygen, provide useful case-studies to reflect on the factors which influenced the development of newborn resuscitation during the twentieth-century. One important factor which is analysed in detail is the formation of a network of scientists and clinicians with a shared interest in the neonate, which emerged during the 1950s. This ‘neonatal network’ has been identified and mapped, and its actions are discussed in detail. The thesis argues that the neonatal network played a fundamental role in directing neonatal research and care during the 1950s and 1960s. The case of newborn resuscitation is used to highlight the interactions of the network members.

The history of newborn resuscitation is used to reflect on some wider themes of late-twentieth century medicine. It highlights the divided role of the post-war academic clinician, who was responsible for both clinical care and research. It also illustrates common trends such as the move towards super-specialization in medicine, the increasingly technological nature of medical care and the growing authority of science in the clinic.

The research has analysed a variety of sources including the archives of the Ministry of Health, Medical Research Council, Scottish Home and Health Department, the Neonatal Society and National Birthday Trust Fund. Oral histories have been used to map the relationships forged between key actors. A variety of published resources, including journal articles, textbooks and conference proceedings, have also been studied to track both the changes in neonatal care and changes in the physiological understanding of the newborn.

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I will also like to extend my gratitude to all the staff and students of the Centre for the History of Medicine, University of Glasgow, for the friendship over the past three years. A special thanks to my close friends and family for supporting me through this, at times challenging, project.

Candidate's declaration

I declare that the work recorded in this thesis is totally my own work and that it is my own composition. No part of this work has been submitted for any other degree.

Rachel McAdams, 2008

Introduction

> Despite the early availability of methods similar to those to be outlined in this report, equally sincere proposals continue to be made for the use of ineffectual and potentially dangerous techniques such as “intragastric oxygen” [and] “cutaneous respiration” … Unfortunately, the relative effectiveness of these resuscitative techniques is still highly controversial.[1]

Writing in 1965 Bradley Smith and Frank Moya (above) lamented the lack of an agreed method of treating the asphyxiated newborn, that is, the newborn who failed to begin spontaneous respirations at birth.[2] It may seem surprising that such an early and critical medical intervention in the life of a human remained so controversial by the mid-1960s, especially considering other advances in medicine made by this time. However, further investigation reveals widespread disagreement over the issue of newborn resuscitation up until the late 1960s. Despite this obvious medical controversy little has been written on the subject or on the medical care of the neonate in the twentieth century more generally.

A survey of the writings on the care of the newborn in the twentieth century, which will be outlined in the next section, reveals the failure of medical historians to analyse this area of medicine to date. Despite the vast amount of literature on the history of obstetrics and childbirth, few historians have specifically looked at the care of the neonate. The histories that have been written either recount the stories of ‘Great’ men and women who pioneered advances in newborn care, or consist of wide-ranging surveys of neonatal care from antiquity, which take the form of the linear accumulation of knowledge and progress. These historical narratives have mainly been constructed by practitioner-historians and lack analysis within wider historical and social contexts. They are usually overly simplistic positivist

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1 Smith, B. (1965). "Resuscitation of the depressed newborn." *Anesthesiology* **26**: 549-561.

2 Asphyxia neonatorum is the formal medical terminology for the newborn baby who fails to begin spontaneous respirations at birth. However a number of informal terms were also used throughout the period discussed to describe this disorder. These included birth asphyxia, newborn asphyxia, and neonatal asphyxia. These terms were used interchangeably by the clinicians and scientists and there appears to be no correlation of which types of actors preferred a particular term. This variation in the name given to the disorder perhaps reflects the lack of consensus, during the period discussed, on the cause and treatment of asphyxia neonatorum.

There are various factors which can cause a newborn to fail to initiate respiration, these include: depressant effects of obstetrical anaesthesia and analgesia; prematurity; and amniotic fluid in the lugns. Some of these factors will be discussed in later chapters.

narratives which praise the 'advances' and ridicule the 'deviations'. It is hoped that this thesis will provide a deeper, complex and more nuanced historical analysis of newborn resuscitation after the Second World War than has previously been presented by such practitioner-historians.

As a novel late twentieth-century medical subspecialty, the history of neonatology can also be used to reflect on the development of late twentieth-century medicine. Again this is a much neglected period in history, as will be discussed below in detail. Those who have studied twentieth-century medicine have tended to concentrate on the decades before World War II. Their writings have uncovered a number of trends characteristic of medicine in the twentieth century, most notably the increasingly scientific nature of medicine and the rise of clinical research.[3] Both these new trends transformed medical practice, research and education in the twentieth century.

It is hoped that, by examining the historically overlooked development of neonatology through the lens of newborn resuscitation, this thesis will contribute to the growing literature on late twentieth-century medicine. The history of newborn resuscitation after World War II reflects the emerging intimate relationship between science and medicine in the twentieth century which resulted in the emergence of biomedicine. It includes not only the successful collaborative partnerships between scientists and clinicians and the changing role of the post-war clinician, but also reflects on the tensions and conflicts which emerged as medicine was transformed by biomedicine and also the rise of clinical research.

The following chapters aim to explore why the care of newborns, specifically asphyxiated newborns, was transformed so dramatically from the 1930s through to the 1960s. They will also challenge the simplistic linear positivist history of newborn resuscitation which has thus far been presented. The historical analysis will apply a social constructivist approach influenced by the Strong Programme in the sociology of scientific knowledge to construct a more complex and

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Throughout the thesis the term biomedicine is used to denote the merger of science and medicine which occurred during the twentieth century and was concerned with knowledge production, theory and research generated by both the basic biological sciences and medicine.

Clinical research refers to the branch of medical science which conducts research in the clinical sphere to determine the safety and effectiveness of therapeutics, medical devices, treatment regimes and diagnostic procedures intended for human use.

sociologically informed history of newborn resuscitation in the mid-twentieth century.[4]

The research was constrained for various reasons and so it is important that the parameters of the thesis are explained first. The analysis began from 1929 as this marked the publication of the first resuscitative methods for newborns which were identified as ‘physiologically’ or ‘scientifically’ informed, these included the Drinker respirator, Yandell Henderson’s inhalatory method and Pauluel Flagg’s intubation with positive pressure ventilation.[5] These three methods were identified by the medical community at the time as representing a definite break from past practices and heralded the dawn of a ‘modern’ and ‘scientific’ approach to newborn resuscitation. They also contributed to the first widespread reviews of newborn care and resuscitation more generally in Britain and America.

From 1929 onwards physiologists also began to take a sustained interested in fetal and neonatal physiology, specifically respiratory physiology, and asphyxia neonatorum became an area of interest for several key researchers. It will be argued that this interwar period, starting in 1929, began to see a shift in how the newborn was viewed by both physiologists and clinicians. The newborn began to be viewed as unique physiologically and as existing in a transitional state. This interwar period also witnessed the first evidence of involvement of physiologists in newborn resuscitation, a theme which became increasingly significant after the war.

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Examples of this sociologicall-enlightened history include:
Nicolson, M. and G. Lowis (2009). “The early history of the Multiple Sclerosis Society of Great Britain and Norther Ireland: A study of lay/practitioner interactionin the context of a medical charity.” *Medical History* **46**: 141-174.
Sturdy, S. (2007): “Scientific method for medical practitioners: The case method of teaching pathology in early twentieth century Edinburgh.” *Bulletin of the History of Medicine* **81**: 760-792.

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The Drinker respirator was a negative pressure ventilator. The infant’s body from the neck down was sealed in a chamber. The pressure within this chamber was then increased and decreased cyclically. It was believed that when the pressure falls below that within the lungs, the lungs expand and atmospheric pressure pushes air from outside the chamber in via the person's nose and airways to keep the lungs filled; when the pressure rises above that within the lungs, the reverse occurs, and air is expelled. An image can be found on page 68.

Henderson’s inhalatory method involved placing a mask over the infant’s nose and mouth and supplying a mixture of carbon dioxide and oxygen as a steady stream. An image can be found on page 46.

Flagg’s method used an endotracheal tube to supply an oxygen mixture under intermittent positive pressure directly to the lugs. An image can be found on page 67.

The analysis ends in 1970 because by this point the particular controversy surrounding the most appropriate method of newborn resuscitation had stabilized and the key actors involved in the debates during the 1950s and 1960s had moved onto to researching other areas of newborn care and physiology. This is not to say that the technology and knowledge surrounding newborn resuscitation had become static, but that the research problems and areas of contention examined in the case studies used had stabilized briefly.

Time constraints meant that the research was also limited to selectively choosing the resuscitation methods to investigate. It was decided that the main focus of the research would be on just three resuscitative methods which were subject to much debate during the 1950s and 1960s. These three techniques were endotracheal intubation with positive pressure ventilation, hyperbaric oxygen and intragastric oxygen.[6] Some other mechanical methods are also examined in less depth but again it was decided that the use of stimulant drugs would not be discussed, although they were very popular during the period analysed.

One of the key themes of the thesis is the growing interaction between physiology research and medical research. As a result the main actors examined in detail were physiologists and academic clinicians involved in medical research and therefore the thesis mainly examines research rather than everyday medical practice. Undoubtedly the funding of research is an important factor, and is something which other historians have examined, however time limitations have meant that this factor is not examined here. Rather the main focus of the thesis is the interactions between physiological knowledge and research and clinical knowledge and research, examining specifically the relationships between the physiological and clinical understanding of the asphyxiated newborn and the treatment of asphyxia neonatorum.[7]

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Hyperbaric oxygen resuscitation involved placing the newborn within a hyperbaric chamber. The chamber was sealed and an oxygen mixture was continually pumped in. The pressure inside the chamber was cyclically increased and it was believed that under higher pressure more oxygen would be absorbed through the infant's skin and respiratory mucosa. For an image see page 224.

Intragastric oxygen resuscitation involved supplying a steady stream of oxygen via a tube to the infant's stomach. It was believed that sufficient oxygen could be absorbed through the stomach and intestinal mucosa to sustain life. For an image of this method see page 196.

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Respirtory stimulants, such as lobeline and adrenaline, were popular from the late nineteenth

Originally the thesis was going to focus on newborn resuscitation in Britain. However as the research progressed it became clear that during this particular period a key group of actors from both Britain and America emerged as world leaders in both the clinical and physiological aspects of newborn resuscitation and newborn care more generally. It was therefore decided to trace the activities of these key individuals throughout the controversies which arose after World War Two. Therefore geographically the thesis focuses on Britain and America, although there are a few significant contributions mentioned from actors out with these countries.

Writings on the history of newborn care in the twentieth century

In his book, *Death in Childbirth*, Irvine Loudon argues:

> Broadly speaking, the predominant form of infant mortality in the West was post-natal mortality in the nineteenth century, neonatal in the twentieth century. As the twentieth century progressed, the proportion of neonatal deaths in infant mortality increased steadily, and the proportion of early neonatal deaths in neonatal mortality deaths formed by far the largest part of infant mortality.[8]

Despite this apparently dramatic increase in neonatal/perinatal deaths as a proportion of infant mortality during the twentieth century, the history of newborn care in this period has thus far been overlooked by medical historians.[9] Although much has been written on the care of the newborn before 1900, mainly within the vast literature on obstetrics and midwifery, the historical analysis appears to stop in the early decades of the twentieth century. The most notable contributions to date include Jeffrey Baker's examination of the development of the incubator, *The Machine in the Nursery,* and the examination of the Infant Welfare Movement and changes in infant feeding by Richard Meckel, *Save the Babies,* Janet Golden, *A*

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century through to the mid-twentieth century. They could either be injected or sometimes applied to the infant's tongue.

8 Loudon, I. (1992). *Death in Childbirth. An international study of maternal care and amternal mortality, 1800-1950*. Oxford, Clarendon Press. p516.

9 The neonatal period covers the first month of life, and therefore neonatal mortality includes all infant deaths up until the end of the first month of life. The postnatal period refers the period from the end of the first month of life until the end of the first year.

The perinatal period includes all stillbirths and neonatal deaths within the first seven days of life.

Social History of Wet Nursing in America, Rima Apple, *Mothers and Medicine*, and Deborah Dwork, *War is Good for Babies and Other Young Children*.[10] Other notable attempts to address this void include the Wellcome Witness Seminars *Origins of Neonatal Intensive Care in the UK* and *Prenatal Corticosteroids for Reducing Morbidity and Mortality after Preterm Birth*.[11] However, post-war histories of newborn care are noticeably lacking.

This absence may, in part, be due to the increasingly scientific nature of the developing sub-specialty of neonatology after the war, a trend which has also been noticed in the history of science. As the historians Jeff Hughes and Thomas Söderqvist have argued, historians 'have typically been more reluctant to work on post-war and more recent science'.[12] Hughes and Söderqvist argue that the reasons are two-fold: 'first, methodological difficulties concerning the size and complexity of contemporary science and, secondly, political problems concerning its authority in contemporary culture'.[13]

The lack of contributions from medical historians has meant that much of what has been written to date, on the history of neonatology and newborn care in the twentieth century, has been produced by practitioner-historians. These authors are usually retired paediatricians or obstetricians who contributed to the narratives that they recount, and who have become interested in the history of their medical specialty. Their writings often re-tell the stories of the 'Great' men or women who

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Apple, R.D. (1987). *Mothers and Medicine: A social history of infant feeding, 1890-1950.* Madison, University of Wisconsin Press.
Baker, J. (1996). The Machine in the Nursery: Incubator technology and the origins of newborn intensive care. Baltimore, Johns Hopkins University Press.
Dwork, D. (1987). *War is Good for Babies and Other Young Chidlren: A history of the infant and child welfare movements in England, 1898-1918*. London, Tavistock.
Golden, J. (1996). *A Social History of Wet Nursing in America: From breast to bottle*. New York, Cambridge University Press.
Meckel, R. (1990). *Save the Babies. American public health reform and the prevention of infant mortality, 1850-1929*. Baltimore & London, Johns Hopkins University Press.

11

Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust.
Reynolds, L. and E.M. Tansey. (Eds.) (2000). *Clinical Research in Britain, 1950-1980*. London, Wellcome Trust.
Reynolds, L. and E.M. Tansey. (Eds.) (2005). *Prenatal Corticosteroids for Reducing Morbidity and Mortality After Preterm Birth*. London, Wellcome Trust.

12

Hughes, J. and T. Söderqvist (1999). "Why is it so difficult to write the history of contemporary science?" *Endeavour* **23**(1): 1-2.

13

Ibid.

are considered to have made significant contributions to the development of newborn care. Good examples of this type of writing are the numerous short historical pieces written by Professor Peter Dunn and published in the *Archives of Disease in Childhood Fetal and Neonatal Edition* over the past twenty years.[14] Although very informative, and a good general resource, these articles are often tinged with triumphalism and present a narrow and simplistic view of the development of the sub-specialty. By only focusing on the actions of individuals these histories neglect the broader context within which they worked.[15]

Other simplistic practitioner-histories of neonatology include broad reviews of neonatal medicine, which recount the 'major' or 'significant' events in newborn care since the nineteenth century. Many of these have been written by some of the 'Great' men and women of neonatology, such as Mary Ellen Avery, who was involved in the discovery of surfactant, and William Silverman, who helped identify the cause of retrolental fibroplasia.[16] The articles normally have quite grand and ambitious titles, such as: 'A Century of Neonatal Medicine'; 'Neonatology (Pioneers and Modern Ideas)'; 'A 50-year Overview of Perinatal Medicine'; and 'A

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A list of Dunn's articles can be found at http://www.neonatology.org/tour/history.html, a website which he also manages.

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Some prime examples of these 'great men' histories include:
Dunn, P. (2001). "Julius Hess, M.D. (1876-1955) and the premature infant." *Archives of Disease in Childhood, Fetal and Neonatal Edition* **85**:142.
Dunn, P. (2001). "Wildelm Conrad Roentgen (1845-1923), the discovery of x raysand perinatal diagnosis." *Archives of Disease in Childhood, Fetal and Neonatal Edition* **84**(2): F138-139.
Dunn, P. (2002). "Sir Leonard Parsons of Birmingham (1879-1950 and antenatal paediatrics." *Archives of Disease in Childhood, Fetal and Neonatal Edition* **86**(1):F65-67.

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Surfactant was identified in 1959 as a wetting agent required for the expansion of the alveoli at birth. A lack of surfactant was linked to development of respiratory distress in newborns. Retrolental fibroplasia, or blindness of prematurity, was identified during the 1950s, and it was soon linked to the uncontrolled use of oxygen therapy in neonates.

Silverman, W. (1989). "Neonatal pediatrics at the century mark." *Perspectives in Biology and Medicine* **32**(2): 159-170,
Avery, M. (1992). "A 50-year overview of perinatal medicine." *Early Human Development* **29**: 45-50,
Avery, M. (1998). "Neonatology (pioneers and modern ideas)." *Pediatrics* **102**(Supp 1): 270-271.
Silverman, W. (1992). "Overtreatment of neonates? A personal retrospective." *Pediatrics*: 971-976,
Silverman, W. (1994). "Letter to the editor: 'writing history is like trying to nail jelly to the wall'-robin winks." *Acta Paediatrica* **83**: 684.

Decimillennium in Neonatology'.[17] They also have equally ambitious aims for such short articles. As Russel Viner has argued:

> In these histories, the accumulation of knowledge and progress itself are understood as historical forces. Only the voices of medicine and science are heard, and all other elements of the political and social discourse are tacit.[18]

However, some practitioner-historians have produced more substantial histories of newborn care. The most expansive to date is Thomas E. Cone Jr's *History of the Care and Feeding of the Premature Infant* published in 1985.[19] Although Cone also attempts to recount the history of newborn care from antiquity to modern times, his writing is more nuanced than the articles mentioned above and it considers some of the wider social, economic and political changes which influenced the care of the newborn over time. Another useful and more recent attempt to give a perspective on the history of newborn care in Western medicine can be found in Murdina MacFarquhar Desmond's book *Newborn Medicine and Society. European Background and American Practice (1750-1975).*[20]

A common theme in many of these practitioner-histories is the idea that newborn medicine has been plagued by 'errors' and 'misadventures', the most well known account being the case of retrolental fibroplasia.[21] A good example of this historiography can be found in the series of articles by Alex F Robertson, 'Reflections on Errors in Neonatology', published in the *Journal of Perinatology* in

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Avery, M. (1992). "A 50-year overview of perinatal medicine." *Early Human Development* **29**: 45-50,
Avery, M. (1998). "Neonatology (pioneers and modern ideas)." *Pediatrics* **102**(Supp 1): 270-271,
Lussky, R. (1999) "A century of neonatal medicine." *Minnesota Medicine* **82**, http://www.mnmed.org/publications/MnMed1999/December/Lussky.cfm?PF=1,
Nelson, N. (2000). "A decimillenium in neonatology." *Journal of Pediatrics* **137**: 731-735.

18

Viner, R. (1999). "Using the history of pediatrics." *Health and History* **1**: 161-167. p165.

19

Cone, T. (1985). *History of the Care and Feeding of the Premature Infant*. Boston/Toronto, Little Brown and Company.

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MacFarquhar Desmond, M. (1998). *Newborn Medicine and Society. European background and American practice (1750-1975).* Austin, Eakin Press.

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The key book on this particular episode in the history of neonatology is:
Silverman, W. (1980). *Retrolental fibroplasia: A modern parable.* New York & London, Grune and Stratton.

2003.[22] Robertson constructs a three-part history of neonatology in the twentieth century divided into: the “Hands-Off” years, 1920 to 1950; the “Heroic” years, 1950 to 1970; and finally the “Experienced” years, 1970 to 2000. This again is an example of a simplistic, positivist and triumphalist history of neonatology.

One of the developments traced by Robertson, through his three-part history, is that of newborn resuscitation. In Robertson’s historiography the care of the newborn during the interwar years was ‘hands-off’, viewed as ‘a nursing task comprised primarily of warming, feeding, and isolation’.[23] Resuscitation, if attempted at all, was restricted to clearing of the airways with a suction device and possibly mouth-to-mouth administration of air. However, after the war, he argues that the ‘hands-off’ attitude to newborn care began to shift, and there was a period of ‘striking care changes and errors’ from 1950 to 1970, which eventually gave way to the ‘Experienced’ years.[24] The ‘Experienced’ years after 1970 witnessed ‘a refinement of many of the new methods introduced … [and] fewer errors’.[25] Tracing newborn resuscitation through this period, the ‘Heroic’ years saw the introduction of an array of novel resuscitative devices, one of which, the Bloxsom Air Lock, was examined by Robertson.[26] The Bloxsom Air Lock, a positive-negative pressure cycling chamber, within which the asphyxiated infant was placed, is described as an ‘error’ and ‘deviation’ in the positivist history of intubation and positive pressure resuscitation methods.[27]

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22 Robertson, A. (2003a). "Reflections on errors in neonatology i: The 'hands-off' years, 1920 to 1950." *Journal of Perinatology* **23**: 48-55,
Robertson, A. (2003b). "Reflections on errors in neonatology ii: The 'heroic' years, 1950 to 1970." *Journal of Perinatology* **23**: 154-161,
Robertson, A. (2003c). "Reflections on errors in neonatology iii: The 'experienced' years, 1970 to 2000." *Journal of Perinatology* **23**: 240-249.

23 Robertson, A. (2003a). "Reflections on errors in neonatology i: The 'hands-off' years, 1920 to 1950." *Journal of Perinatology* **23**: 48-55. p48.

24 Ibid. p48.

25 Robertson, A. (2003a). "Reflections on errors in neonatology i: The 'hands-off' years, 1920 to 1950." *Journal of Perinatology* **23**: 48-55. p48.

26 Robertson, A. (2003b). "Reflections on errors in neonatology ii: The 'heroic' years, 1950 to 1970." *Journal of Perinatology* **23**: 154-161.

27 Ibid.

This view of the history of newborn resuscitation, as a progressivist narrative of the rise of intubation with positive pressure ventilation amidst the occasional distracting adoption of ‘ineffective’, ‘unscientific’ and ‘erroneous’ devices, is a historiography shared by other practitioner-historians. These writings normally take the form of brief historical introductions in medical textbooks or historical reviews in medical journals. A number of techniques, including the Bloxsom Air Lock, intragastric oxygen, and hyperbaric oxygen, if mentioned at all, are parcelled together as ‘deviations’, ‘misadventures’ or ‘setbacks’, which served only to delay the eventual and inevitable adoption of positive pressure ventilation, as the most appropriate resuscitative technique.[28] These writings share the view that intubation with positive pressure insufflation was adopted as the ‘most effective’ treatment for asphyxia neonatorum because it worked, and that the other methods ‘failed’ because they did not.

Examples of these writings include Goldsmith and Karotkin’s *Assisted Ventilation of the Neonate*, which provides a brief history of assisted ventilation tracking developments in positive pressure ventilation, with no mention of the alternative devices and techniques used in the post-war period.[29] Similarly Alistair Philip’s ‘The Evolution of Neonatology’, gives no mention to these ‘misadventures’, instead stressing that there was a ‘benign neglect ‘ of asphyxiated newborns until the 1950s, when Virginia Apgar introduced her scoring system and began to intubate babies.[30]

Although some practitioner-historians completely neglect the alternatives to intubation and positive-pressure ventilation, others dedicate entire articles to the anecdotal description of these ‘deviations’ and ‘misadventures’, set within the backdrop of the triumphant rise of positive pressure methods. Three prime examples of this type of article are O’Donnell *et a*l’s ‘Pinching, electrocution, ravens’ beaks, and positive pressure ventilation: a brief history of neonatal resuscitation’, Kendig *et al*’s ‘The Bloxsom Air lock: A historical perspective’, and

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28 Ibid.

29 Goldsmith, J. and E. Karotkin (1996). "Introduction to assisted ventilation". in *Assisted ventilation of the neonate*. J. Goldsmith and E. Karotkin (Ed.). Philadelphia, WB Saunders Co.**:** 1-19.

30 Philip, A. G. S. (2005). "The evolution of neonatology." *Pediatric Research* **58**(4): 799-815.

Tonse N.K Raju's 'History of Neonatal Resuscitation. Tales of Heroism and Desperation'.[31]

An example of a slightly more detailed and historically-enlightened article can be found in Smith and Vidyasagar's *Historical Review and Recent Advances in Neonatal and Perinatal Medicine*, with a chapter on 'Birth Asphyxia' by Philip J. Goldstein.[32] However, Goldstein does tend to fall back onto the 'Great' men and women and 'milestone' based histories described above. Often these practitioner-histories have an innate bias, and serve as a means of defending the authority of modern medical science as well as supporting the autonomy of the sub-specialty of neonatology and its so-called 'pioneers' and 'Great' men and women. As Viner has argued:

> While professional historians have little interest in these judgements about saints and sinners in medicine, these histories do provide models of desirable personal and professional practice, illustrating the kinds of role models paediatricians are told they should emulate … [they] provide validation for the practice of medicine for children in both scientific and moral terms … [they] are therefore valuable for the pediatric profession, encouraging productivity, ethical behaviour and professional bonds among individual practitioners.[33]

It would appear that there is a lack of a deeper and more nuanced analysis of the history of newborn resuscitation in the twentieth century, which accounts for the role of broader social factors influencing changes in medical practice. It is hoped that this thesis will provide a revisionist historiography for newborn resuscitation in the twentieth century, which directly challenges some of the common themes of the practitioner-histories described above, which are epitomized by Robertson's

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Raju, T. (1999). "History of neonatal resuscitation. Tales of heroism and desperation." *Clinics in Perinatology* **26**(3): 629-640,
Kendig, J. W., P. G. Maples, et al. (2001). "The bloxsom air lock: A historical perspective." *Pediatrics* **108**(6): e116,
O'Donnell, C., A. Gibson, et al. (2006). "Pinching, electrocution, raven's beaks, and positive pressure ventilation: A brief history of neonatal resuscitation." *Archives of Disease in Childhood. Fetal and Neonatal Edition* **91**: F369-373.

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Goldstein, P. (1980). "Birth asphyxia". in *Historical review and recent advances in neonatal and perinatal medicine*. G. Smith and D. Vidyasagar (Ed.). Illinois, Mead Johnson Nutritional Division. **vol.1:** 177-184.

33

Viner, R. (1999). "Using the history of pediatrics." *Health and History* **1**: 161-167. p165.

'Errors in Neonatology' articles. This revisionist history will be more sociologically informed.

It is also hoped that this history of newborn resuscitation can be used to reflect on the emergence of neonatology during the mid- to late-twentieth century, and therefore contribute to the limited historical writings available. Further, by analysing the development of newborn resuscitation and more broadly neonatology, it is hoped that the thesis will also contribute to a broader understanding of late twentieth-century medicine.

Writings on late twentieth-century medicine

In their introduction to the *Companion to Medicine in the Twentieth Century*, Rodger Cooter and John V Pickstone comment on the 'paucity of historical studies' on medicine in the twentieth century, and argue that 'those that exist refer primarily to the first half of the century', with the Second World War considered a cut-off date.[34] Similarly Virginia Berridge observes that until recently '1950 was the end of history', with an obvious lack of historical writings on the post-war period.[35] Some good general reviews of late twentieth-century medicine can be found in Berridge's *Health and Society in Britain Since 1939*, Hardy and Tansey's 'Medical enterprise and global response, 1945-2000' in Bynum *et al*'s *The Western Medical Tradition, 1800 to 2000*, and Hardy's *Health and Medicine in Britain Since 1860*.[36]

Some of the key themes, or characteristics, of late twentieth-century medicine identified thus far include: the rise of clinical science; the merger of science and medicine to create biomedicine; an increase in techno-centric medicine; super-specialization and a trend towards reductionism; and the importance of state

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34 Cooter, R. and J. Pickstone (Eds.) (2003). *Companion to Medicine in the Twentieth Century*. London, Routledge.

35 Berridge, V. (2000). "Health, medicine and social policy: The rise of the longer twentieth century?" *Journal of Contemporary History* **35**: 667-677. p667.

36 Berridge, V. (1999). *Health and Society in Britain since 1939*. Cambridge, Cambridge University Press,
Bynum, W.F., Hardy, A., et al., (Eds.) (2006). *The Western Medical Tradition, 1800 to 2000*. New York, Cambridge University Press.
Hardy, A. (2001). *Health and Medicine in Britain since 1860*. Basingstoke, Macmillan,
Hardy, A. and Tansey, E.M. (2006). "Medical enterprise and the global response, 1945-2000." in *The Western Medical Tradition, 1800 to 2000*. Bynum, W.F., Hardy, A., et al., (Eds.). New York, Cambridge University Press. p405-534.

medicine and the welfare state. Each of these themes has a role to play in the history of newborn resuscitation, so it is useful to consider some of the key historical contributions to date.

As Pickstone has stated, the twentieth century has been described as ‘the century of medical science’.[37] It has been argued that from the late nineteenth century ‘medical knowledge, practice, and policy were radically transformed. Medicine and a new science became powerfully interconnected during this period’ … as medicine evolved into biomedicine.[38] Some authors claim that this transformation was characterised by the utilization of scientific knowledge, practices and technologies. Another important theme in twentieth-century medicine was the rise of contemporary clinical science which was also linked to the reform of medical education, research and practice from the late nineteenth century through to the early decades of the twentieth century.

Much has been written on this early phase of this merger of science and medicine, viewed as a clash of the ‘old and new’, the ‘traditional and innovative’, ‘the bench and the bedside’, or the ‘clinic and the laboratory’.[39] Christopher Lawrence has provided a detailed analysis of this clash as it occurred within Edinburgh Medical School, 1919-1930.[40] In part this involved the move away from pathological anatomy, seen in the nineteenth century as the science of medicine, towards ‘a method of physiological problem solving based on experimental animal studies in the laboratory’ from the turn of the twentieth century.[41] Lawrence argues that those

37

Pickstone, J. (2003). “Production, community and consumption: The political economy of twentieth-century medicine”. in *Companion to Twentieth Century Medicine*. R. Cooter and J. Pickstone (Eds.). London, Routledge: 1-19. p1.

38

Brandt, A.M. and M. Gardner (2003). “The golden age of medicine?” in *Companion to Twentieth Century Medicine*. R. Cooter and J. Pickstone (Eds.). London, Routledge: 21-37. p21.

39

Cunningham, A. and P. Williams (Eds.) (1992). *The Laboratory Revoluntion in Medicine*. Cambridge & New York, Cambridge University Press.
Lawrence, C. (2005). *Rockerfeller Money, the Laboratory and Medicine in Ediburgh, 1919-1930. New science in an old country*. Rochester, University of Rochester Press.
McGehee Harvey, A. (1981). *Science at the Bedside. Clinical research in American medicine 1905-1945*. Baltimore &London, Johns Hopkins University Press.

40

Lawrence, C. (2005). *Rockerfeller Money, the Laboratory and Medicine in Edinburgh, 1919-1930. New science in an old country*. Rochester, University of Rochester Press.

41

Ibid. p329..

in favour of the ‘traditional’ medicine feared that this ‘modernization’ and ‘standardization’ of medicine through the introduction of science eroded the ‘individualism’ and ‘medical art’ prevalent at the time.[42]

Reformers called for increased involvement of universities in medical schools, leading to the creation of full-time clinical professorships and the setting up of clinical research departments within medical schools. In Britain these changes were epitomised with the establishment of the Royal Postgraduate Medical School at Hammersmith Hospital, London, which had the responsibility for providing postgraduate medical education based on clinical research from the 1930s.[43] Much has been written on these pre-war changes in both medical research and practice.[44]

Andrew Hull has studied these changes in a more local setting as they occurred in Glasgow during the interwar period. In his article ‘Hector’s House: Sir Hector Hetherington and the Academicization of Glasgow Hospital Medicine before the NHS’, Hull describes how Glasgow medicine was re-organized to accommodate the changes which would accompany the adoption of clinical science in medical research, teaching and practice.[45] In his second article, ‘Teamwork, Clinical Research, and the Development of Scientific Medicine in Interwar Britain: The “Glasgow School” revisited’, Hull goes onto to describe the unique type of clinical

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42

Ibid. p331.

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Booth, C. (1985). “Medical science and technology at the Royal Postgraduate Medical School: The first 50 years”. BMJ 291: 1771-1779.
Calnan, J. (1985). The Hammersmith: The first 50 years of the Royal Postgraduate Medical School at Hammersmith Hospital. Lancaster, MTP.

44

Bonner, T.N. (1995). *Becoming a Physician: Medical education in Britain, France, Germany and the United States.* New York, OUP.
Booth, C. (1985). “Medical science and technology at the Royal Postgraduate Medical School: The first 50 years”. *BMJ* **291**: 1771-1779.
Sturdy, S. (2007). “Scientific method for medical practitioners: The case method of teaching pathology in early twentieth century Edinburgh.” *Bulletin of the History of Medicine* **81**: 760-792.

45

Hull, A. (2001). “Hector’s House: Sir Hector Hetherington and the academicization of Glasgow hospital medicine before the NHS.” *Medical History* **45**: 207-242.
Another good example of this local analysis can be found in: Sturdy, S. (1992). “The political economy of scientific medicine: Science, education and the transformation of medical practice in Sheffield, 1890-1922.” *Medical History* **36**: 125-159.

research which evolved in Glasgow during the interwar years, which was a result of the distinctive medical culture within the city at the time.[46]

Some writings on this interwar period have emphasized the importance of state and national bodies concerned primarily with the promotion and funding of clinical research, such as the Medical Research Council, in Britain, and the National Institute of Health, in the US.[47] Other authors have chosen to document the many therapeutic advances achieved during this ‘Golden Age’, such as antibiotics and insulin.[48] However, little has written about the mid-to-late twentieth century. The Second World War, universally accepted as having a major impact on both science and medicine, appears to be the end point of the history of clinical science. The rise of clinical science has also been linked to a reductionist approach to medicine in the twentieth century, involving a move towards super-specialization, which also met with resistance amongst the medical community.[49]

As Carsten Timmerman and Julie Anderson explain in the introduction to *Devices and Designs*, during the twentieth century:

> Medical technologies changed diagnostic procedures and treatment regimes, and technical innovations were closely associated with new approaches in medical science and with the rise of what we call

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Hull, A. (2007). “Teamwork, clinical research, and the development of scientific medicines in interwar Britain: The “Glasgow School” revisited.” *Bulletin of the History of Medicine* **81**: 569-596.

47

Harden, V.A. (1986). *Inventing the NIH: Federal biomedical research policy, 1887-1937*. Baltimore, Johns Hopkins University Press.
Austoker, J. and L. Bryder (Eds.) (1989). *Historical Perspectives on the Role of the MRC: Essays in the history of the Medical Research Council of the United Kingdom and its predecessor the Medical Research Committee, 1919-1953*. Oxford and New York, OUP.

48

Bliss, M. (1982). *The Discovery of Insulin*. Chicago, University of Chicago Press.
Paul, J.R. (1971). *A History of Poliomyelitis*. New Haven & London, Yale University Press.
Wainwright, M. (1990). *Miracle Cure: The story of penicillin and the golden age of antibiotics*. Oxford & Cambridge, Blackwell.

49

Lawrence , C. (1985). “Incommunicable knowledge: Science, technology and the clinical art in Britain 1850-1914.” *Journal of Contemporary History* **20**(4):503-520.
Lawrence, C. and G. Weisz (Eds.) (1998). *Greater than the Parts, Holism in Biomedicine, 1920-1950*. New York, OUP.
Weisz, G. (2006). *Divide and Conquer: A comparative history of medical specialization*. New York, OUP.

> biomedicine, the marriage between laboratory science and medical practice.[50]

Historians have examined case-studies of some of the earliest medical technologies which helped to shape and change early twentieth century medicine, including X-rays and the electrocardiograph.[51] Although often met with some suspicion and resistance, these new medical technologies proved their worth during the First World War, and contributed to the widespread development of a more techno-centric medicine of the twentieth century. Similarly the Second World War proved an ideal environment for the production and trial of new medical technologies such as mobile X-ray machines and respiratory support devices. The 1950s and 1960s witnessed a transformation in hospital medicine with novel technologies such as ultrasound, the medical laser and pacemakers introduced into everyday medical practice.[52] Likewise, the history of newborn resuscitation after the war witnessed the development of a number of novel resuscitative devices, which had their roots in wartime research. More generally the post-war newborn nursery was transformed with the addition of a vast array of medical technologies such as ventilators and heart monitors.[53]

Some of these key themes and characteristics of late twentieth-century medicine are apparent in the history of newborn resuscitation which I will present in the

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Timmerman, C. T. and J. Anderson, Eds. (2006). *Devices and designs. Medical technologies in historical perspective*. Basingstoke & New York, Palgrave Macmillan. p1.

51

Blume, S. (2003). “Medicine, technology and industry”, in *Companion to Twentieth Century Medicine*. R. Cooter and J. Pickstone (Eds.). London, Routledge: 171-185.
Burrows, E.H. (1986). *Pioneers and the Early Years. A history of British radiology*. Alderney, C.I., Colophon.
Knight, N. (1986). “The new light: X-rays and medical futurism.” in *Imagining Tomorrow.* J.J. Corn (Ed.). Cambridge, MIT Press: 10-34.
Lawrence, C. (1985). “Moderns and ancients: The “new cardiology” in Britain 1880-1930.” *Medical History* **Supp 5**: 1-33.
Pickstone, J. (Ed.) (1999). *Medical Innovationin Historical Perspective*. Basingstoke & London, Macmillan Press Ltd.

52

Koch, E. B. (1993). "In the image of science? Negotiating the development of diagnostic ultrasound in the cultures of surgery and radiology." *Technology and Culture* **34**(4): p858-893,
Lawrence, G., Ed. (1994). *Technologies of modern medicine*. London, Science Museum,
Jeffrey, K. (1995). "Pacing the heart: Growth and redefinition of a medical technology, 1952-1975." *Technology and Culture* **36**: 583-624,
Blume, S. (2003). "Medicine, technology and industry". in *Companion to twentieth century medicine*. R. Cooter and J. Pickstone (Ed.). London, Routledge**:** 171-185,
Timmerman, C. T. and J. Anderson, Eds. (2006). *Devices and designs. Medical technologies in historical perspective*. Basingstoke & New York, Palgrave Macmillan.

53 MacFarquhar Desmond, M. (1998). *Newborn Medicine and Society. European background and American practice (1750-1975).* Austin, Eakin Press.p192-212.

following chapters. These themes include the increasingly scientific nature of twentieth-century medicine and the importance of physiology in clinical practice, which resulted in some very productive relationships and also created tensions for actors. As Osmond Reynolds, Professor Emeritus in Neonatal Paediatrics, University of London, during the Wellcome Witness Seminar on the *Origins of Neonatal Intensive Care*, held in 1999, commented on the positive aspects of these trends:

> … all the way along the line in perinatal medicine, there's been this to-ing and fro-ing between animal work, based on physiology … and then defining the questions in babies, and seeing if we could solve them in the animals, and feeding the results back into the babies.[54]

Similarly Nicholas Nelson described the importance of the merging of science and medicine when he described:

> the interface … conducive to multidisciplinary involvement of physiologists and physiologically oriented clinicians, … pediatricians, obstetricians and internists. In fact, I believe this interface to have been the true basis for the development of modern perinatal medicine.[55]

The chapters which followed are placed within these narratives of twentieth-century medicine, and it is hoped they will contribute to a broader understanding of trends in this period of medical history.

Aims and Methodology

The aims of this thesis are three-fold:

1. To comment on the historically over-looked emergence of the sub-specialty of neonatology in the mid- to late-twentieth century.

2. To provide a revisionist history of the development of neonatal resuscitation during the twentieth century, which challenges the simplistic and positivist narratives written by practitioner-historians, by using specific

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54 Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust. p15-16.

55 Nelson, N. (1980). "Perinatal medicine". in *Historical review and recent advances in neonatal and perinatal medicine.* G. Smith and D. Vidyasagar (Ed.). Illinois, Mead Johnson Nutritional Division. **vol. 1:** 3-8. p5.

case studies of techniques which gained varying popularity during the same period.

3. To contribute to the growing historical and sociological literature on late twentieth-century biomedicine, reflecting on tensions between the laboratory and the bedside; the increasing technical and scientific nature of medicine; and super-specialisation in medicine.

These aims have been achieved through detailed analysis of medical practice using a combination of medical textbooks, articles in medical journals and oral histories. The relationship and tension between medicine and physiology becomes apparent through these sources and also through the use of physiology texts in books and journals, as well as the archives of the Neonatal Society. My analysis of the debates which arose surrounding the different techniques of resuscitation has also been enriched by the study of government documents and reports held in the archives of the Medical Research Council, Ministry of Health, and the Scottish Home and Health Department, and the archives of the Neonatal Society and oral histories. Explanation of how these sources have been used can be found in the chapter outline below.

The main empirical chapters do not include discussion of sociological theory. However, the thesis as a whole is implicitly influenced by certain ideas from the sociology of science. Most significantly this research is informed by the ‘Strong Programme’ in the sociology of scientific knowledge, which argues that the intrinsic truth of an idea is not the only reason for its popularity.[56] Rather, as Barry Barnes and David Bloor have argued, my research presupposes that the truth of an idea is always established and certified through a series of social processes. Of these social processes I have specifically highlighted the role of informal networks, informed by the work of Diane Crane and the ‘invisible college’.[57] The informal ‘neonatal network’ which I describe as emerging during the 1950s and 1960s in Britain and America played an important role in the debates surrounding newborn

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Barnes, B. (1974). *Scientific knowledge and sociological theory*. London & Boston, Routledge & Kegan Paul.
Bloor, D. (1976). *Knowledge and social imagery*. London, Henley & Boston, Routledge & Kegan Paul.

57

Crane, D. (1972). *Invisible colleges. Diffusion of knowledge in scientific communities*. Chicago & London, The University of Chicago Press.

resuscitation, and the actions of this network are discussed in chapter 8 using the theory of ‘boundary-work’, as described by Thomas Gieryn.[58]

My analysis of the overall history of newborn resuscitation, with the eventual rise in popularity of tracheal intubation and positive pressure ventilation, accompanied by the growing authority of the neonatal network, is further informed by Scott Frickel and Neil Gross’ ‘General Theory of Scientific/Intellectual Movements’.[59] Their discussion of why scientific/intellectual movements (SIMs) form and succeed, aids my analysis both of the success of the neonatal network, as well as the decline of the supporters of intragastric oxygen and hyperbaric oxygen. It is hoped that the use of these theories, which will become more explicit in Chapter 8, will further enrich my discussion of the history of newborn resuscitation, and add to the growing literature on the sociology of late twentieth century science and medicine.

Chapter outline

Chapter 2 focuses on the interwar years in Britain and America and challenges the view held by Robertson that this period represented a ‘hands-off’ attitude to newborn resuscitation. A survey of medical textbooks and medical journals evidences the variety of resuscitation methods used from the late nineteenth to early twentieth centuries. By the end of the 1920s an emerging trend in newborn care is identified, as novel resuscitation methods heralded as scientifically-informed and modern were introduced. Another trend identified was the growing interest amongst physiologists in fetal and neonatal physiology, specifically respiratory. Evidence for this is again drawn from journals and some secondary literature. The chapter details the birth of neonatal physiology and the research of Joseph Barcroft, Yandell Henderson and Nicholson J Eastman and discusses how this research changed both clinicians’ and physiologists’ conception of the neonate. As a further challenge to the practitioner-histories, the chapter provides wider analysis of social and political forces which contributed to these trends in

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Gieryn, T. F. (1983). "Boundary-work and the demarcation of science from non-science: Strains and interests in professional ideologies of scientists." *American Sociological Review* **48**(Dec): 781-795.
Gieryn, T. F. (1999). *Cultural boundaries of science: Credibility on the line*. Chicago, Chicago University Press.

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Frickel, S. and N. Gross (2005). "A general theory of scientific/intellectual movements." *American Sociological Review* **70**(Apr): 204-232.

both physiology and medicine, illustrating that changes in medical practice and knowledge are not simply due to the accumulation of knowlegde.

Chapter 3 continues to challenge the practioner-historians historiography. An important theme in neonatology, which first emerged during the interwar years, was the involvement of two new groups of clinicians, namely paediatricians and anaesthetists. However this theme has been neglected in the literature so far. This chapter addresses this gap in the historiography and analyses the impact that these new sets of clinicians had on newborn care, specifically neonatal resuscitation, in both Britain and America during the interwar and postwar period.

Chapter 4 prevents a much more complex history of newborn resuscitation, which again challenges the positivist narrative. It examines the plethora of novel resuscitative techniques introduced during the interwar years and after WWII, using medical journals and medical textbooks to chart their popularity. It then focuses on the use of positive pressure ventilation and the discussions between physiologists and clinicians over the relative effectiveness of its application via a face-mask or endotracheal tube. These debates first arose during the interwar years and are traced through to the late1950s.

Chapter 5 begins by explaining some of the factors which contributed to the continued interest in neonatal mortality after WWII. It uses evidence from a number of published mortality surveys including the 1958 British Perinatal Mortality Survey and the National Birthday Trusts Archives. The post-war physiologists in Britain, Kenneth Cross and Geoffrey Dawes, who carried on Barcroft’s research, are introduced. Both Cross’ and Dawes’ post-war research is discussed in detail as it evidences their emergence as international leaders in the field of neonatal respiratory physiology. Physiologists had begun to gain a voice in the clinical debates surrounding newborn resuscitation during the interwar years, and this trend was again evident after the war. These neonatal physiologists became members of a network of both clinicians and scientists who became world leaders on neonatal care during the 1950s and 1960s. The members of this network were mainly based in Britain and the east coast of America. Oral history interviews and the archives of the Neontal Society were used to map the development of this network and to examines its role in dictating and influencing newborn resuscitation, specifically the promotion of endotracheal intubation, during the 1950s.

Chapter 6 provides a case-study approach to analysing the role of the neonatal network in directing newborn resuscitation and reflects on the wider landscape of newborn care during the 1950s. The rapid rise to popularity of intragastric oxygen in Britain and America is mapped through analysis of medical journals and textbooks. Members of the ‘neonatal network’ in both America and Britain were soon mobilized towards the end of the 1950s and produced experimental physiological evidence to challenge the method’s effectiveness. Again this is mapped through analysis of the medical literature and oral histories.

Chapter 7 analyses a second case-study on the controversy which erupted surrounding the use of hyperbaric oxygen for newborn resuscitation during the early 1960s in Britain. Hyperbaric oxygen did not gain the same level of popularity as intragastric oxygen, but the controversy surrounding it played a much more important role in cementing the authority of the neonatal network members in directing newborn care. It also contributed to the growing dominance of physiology and physiologists in the clinical care of the neonate. The arhives of the MRC, Scottish Home and Health Department, the Ministry of Health, oral histories and medical journals and textbooks were used to examine the fate of hyperbaric oxygen.

Chapter 8 discusses overall how the history of newborn resuscitationpresented contributes to the literature already available. It reflects on the role of the neonatal network and wider social forces on the changes discussed in chapters 5, 6 and 7, employing some theories from the sociology of science, including Thomas Gieryn’s boundary-work and Scott Frickel and Neil Gross’ General Theory of Scientific/Intellectual Movements. Both theories have contributed to the analysis of the actions of the neonatal network members and the debates which arose over intragastric oxygen and hyperbaric oxygen.

Chapter 2

The obstetrician and the resuscitation of the asphyxiated newborn (late C19th -1920s)

Traditionally it was the obstetrician who had medical domain over the newborn infant, although the majority of births were attended to by a midwife. However, it was within the obstetrical texts that medical discussion was had concerning the care of the newborn. To fully understand the changes which occurred in the care of the asphyxiated newborn in Britain and America in the mid-twentieth century, it is necessary to appreciate the nature of the care available for the asphyxiated neonate around the late nineteenth and early twentieth centuries. A picture of this can be re-constructed from a review of obstetrical textbooks during this period, the various short historical pieces found in the introductions to medical textbooks, as well as medical journals, and the limited writings on the history of newborn care.

There is a common assumption amongst practitioner-historians that the early twentieth-century care of the newborn in Britain and America followed a ‘hands-off’ regime.[60] Alex Robertson has argued that, although the newborn fell under the medical jurisdiction of the obstetrician, they were generally cared for by nurses or midwives, who followed a regime of warming, feeding and isolation.[61] However, medical literature from this period suggests otherwise.

The most basic strategies employed almost universally during the early twentieth century involved: firstly clearing the infant’s airway of mucus using a finger, gauze or a suction device; the infant was then swaddled to maintain their body temperature. However, if the infant failed to respond to these basic strategies then they were deemed to be suffering from more serious asphyxiation and a number of different methods were advocated, some unique to particular countries, and others unique to institutions or individual clinicians. These treatments can be broadly divided into two types: those intended to counteract the asphyxia by administering a strong counter stimulus; and those which were based on more invasive

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60 Robertson, A. (2003a). "Reflections on errors in neonatology i: The 'hands-off' years, 1920 to 1950." *Journal of Perinatology* **23**: 48-55.

61 Ibid.

techniques used in the resuscitation of adults. A review of obstetrical texts and medical journals from this period reflects this variety and also illustrates how techniques were often used in combination or in quick succession, as doctors struggled to save the asphyxiated baby.

Before going on to describe these techniques it will be useful to first explain how asphyxia neonatorum was understood by clinicians in Britain and America at this time. During the late-nineteenth and early twentieth centuries the asphyxiated newborn was classified by clinicians under two types: blue asphyxia and white asphyxia.[62] Little was known about the causes of birth asphyxia, and even less was known about how and why a newborn took its first breath. However clinicians agreed that an infant with blue asphyxia was not as severe as an infant with white asphyxia. Blue asphyxsia, or asphyxia livida, was characterised by a blueish-purple coloration of the baby’s skin. The infant was also usually moving, with a strong heart beat and could sometimes be seen to gasp. Those suffering from white asphyxia, or asphyxia pallida, were the more serious cases. These infants appeared very pale, with no movement and had a very slow or inaudible heart beat. The treatment that an asphyxiated newborn received was dependent on the type of asphyxia they were suffering from.

Many of the infants suffering from blue asphyxia were subjected to painful and distressing treatments during the late nineteenth and early twentieth century as a result of the belief that asphyxia could be reversed by a strong counter stimulus. In

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Asphyxia neonatorum had been considered to have two stages: asphyxia livida [blue] and asphyxia pallida [white] since at least the late nineteenth century (see:
Brothers, A. (1896). *Infantile mortality during childbirth and its prevention*. Philadelphia, P Blaikston, Son & Co,
Koplik, H. (1903). *The diseases of infancy and childhood. Designed for the use of students and practitioners of medicine*. London, Henry Kimpton,
Pfaundler, M. and A. Schlossman (1908). *The diseases of children. A work for the practicing physician*. Philadelphia & London, JB Lippincott.

This early identification of the two stage model of asphyxia is contrary to Steve Sturdy’s argument that clinicians and physiologists were only aware of this two-stage progression of asphyxia towards the end of WW1. It is likely that this two-stage conception of asphyxia was limited to obstetricians and paediatricians who were faced with the asphyxiated newborn, who progressed through the two stages if not treated effectively. Sturdy describes clinicians at war faced with soldiers affected by gas poisoning, who viewed this as damage to the lungs rather than asphyxia. Therefore, when he argues that physiologists attempted to introduce these clinicians to a ‘novel’ physiological conception, its novelty lay in its application to gas poisoning rather than a completely new conception of asphyxia. See:
Sturdy, S. (1992). "From the trenches to the hospitals at home: Physiologists, clinicians and oxygen therapy." in *Medical innovations in historical perspective*. J. Pickstone (Ed.). Houndsmill, Basingstoke, Macmillan Press Ltd**:** 104-123.

Europe a popular treatment was the use of contrast baths, which involved alternately dunking the newborn in hot and cold baths in the hope that the environmental stimulation would arouse respiratory movements. This treatment was particularly popular in Scandinavia and remained so up until the 1950s.[63] However, sometimes only the hot or the cold bath would be used in combination with other methods such as rubbing the infant vigorously and holding it near to an open fire.

Other popular counter-stimuli included brandy and mustard, which were popular antidotes to asphyxia in Britain.[64] The infant could be placed in a bath containing mustard or brandy or the substance could be rubbed onto the chest. Again it was hoped that this would invoke a strong sensory reaction, and therefore elicite the first breath. Another strong stimulus was the dilation of the anus, also popular in the late nineteenth century, and which was sometimes combined with blowing air or smoke into the rectum. Slapping of the buttocks or vigorous rubbing were also popular methods.

Some clinicians believed that the asphyxiated newborn resembled the asphyxiated adult, usually adult victims of drowning. These clinicians advocated techniques which were based on the physiological understanding of the resuscitation of the adult. Some involved simply applying the theory of adult resuscitation, whilst others actually involved using the same techniques.

The Schultze method was first advocated during the late nineteenth century and remained very popular during the interwar years.[65] The infant was held by its

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Koplik, H. (1903). *The diseases of infancy and childhood. Designed for the use of students and practitioners of medicine*. London, Henry Kimpton,
Sheldon, W. (1946). *Diseases of infancy and childhood, 5th edition*. London, J & A Churchill Ltd.
Cameron, S., Hewitt, J., et al (1939). *A Glasgow manual of obstetrics, 3rd edition*. Glasgow, University of Glasgow.

64

O'Donnell, C., A. Gibson, et al. (2006). "Pinching, electrocution, raven's beaks, and positive pressure ventilation: A brief history of neonatal resuscitation." *Archives of Disease in Childhood. Fetal and Neonatal Edition* **91**: F369-373.
Sheldon, W. (1940). *Diseases of infancy and childhood, 4th edition*. London, J & A Churchill Ltd.
Cameron, S., Hewitt, J., et al (1939). *A Glasgow manual of obstetrics, 3rd edition*. Glasgow, University of Glasgow.

65

DeLee, J. (1913). *The principles and practice of obstetrics, 1st edition*. Philadelphia and London, WB Saunders & Company.
Williams, J. (1906). *Obstetrics: A textbook for the use of students and practitioners.* New York, D Appleton and Company.
O'Donnell, C., A. Gibson, et al. (2006). "Pinching, electrocution, raven's beaks, and positive

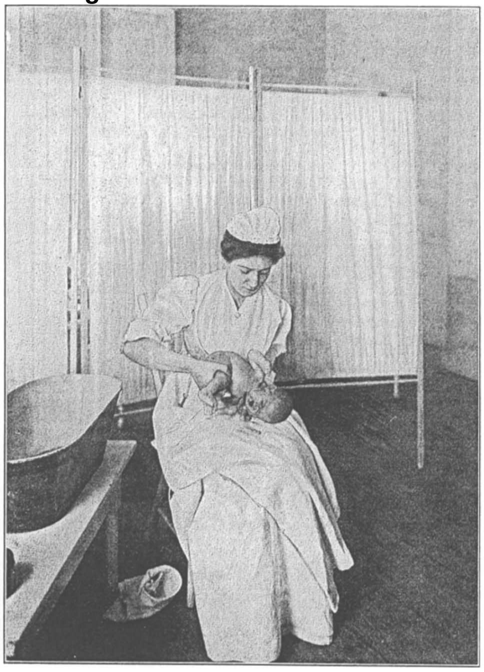
shoulders and alternately swung over the operator's shoulder, so that the infant folded in at the abdomen, and then swung back down again unfolding (see figure 1). It was thought, based on adult resuscitation, that the compression and extension of the thorax would cause passive expiration and inspiration. The Dew method was similar to the Schultze method in principle, although a lot safer in practice. The operator would hold the infant lengthways in his or her lap and alternately fold and unfold the infant to compress the thorax (see figure 2).[66]

Figure 1. The Schultze Method. Image taken from DeLee (1913) The Principles and Practice of Obstetrics

pressure ventilation: A brief history of neonatal resuscitation." *Archives of Disease in Childhood. Fetal and Neonatal Edition* **91**: F369-373.

66 Davis, E. (1904). *Obstetric and gynecologic nursing*. New York & London, WB Saunders & Company.

Figure 2. The Dew Method. Image taken from Davis (1904) Obstetric and Gynecologic Nursing.



Other resuscitation methods, as mentioned, were taken directly from the treatment of adults, and applied to the asphyxiated newborn. Silvester's Method, first advocated for the resuscitation of adults, had been popular from the late nineteenth century through to the 1930s. It involved the abduction and adduction of the arms and shoulders, to increase and decrease the intra-thoracic capacity.[67] The Direct Method, advocated by Benjamin Howard, was also first recommended for the treatment of drowned adults.[68] This involved placing a hard roll of clothing beneath the pit of the patient's abdomen, with them lying face-down. Their head was rested on the forearms, while the operator pushed them from the base of their spine, thus rolling them forward. The patient was then rolled onto his or her back, with hands tied above the head. The operator would push forward using their own weight, with their thumbs, from just below the diaphragm and then release. The hope was that this would relax and expand the diaphragm, thus mimicking

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Pfaundler, M. and A. Schlossman (1908). *The diseases of children. A work for the practicing physician*. Philadelphia & London, JB Lippincott.

68

Howard, B. (1877). "The more usual methods of artificial respiration, with demonstration of the "direct method" of the author." *Lancet* **2**: 194-196.
Howard, B. (1878c). "Two exceptional cases of asphyxia neonatorum; their resuscitation by the direct method of artificial respiration." *Lancet* **1**: 883.
Howard, B. (1878b). "The direct method of artificial respiration for the treatment of apnoea from drowning, anaesthetics, still-birth, etc." *Lancet* **1**: 748-752.

breathing. Mouth-to-mouth resuscitation also crossed over from the treatment of adults, specifically drowned persons, during the nineteenth century.[69]

These types of methods, often referred to as ‘manual’ methods, were concerned with the inflation and deflation of the lungs, and regarded the asphyxiated newborn as resembling the asphyxiated adult physiologically. However, as the newborn began to be viewed as physiologically distinct during the interwar years, clinicians began to realise that adult methods could not simply be applied to the newborn.

There were other techniques which did not fall into these two groups. The Labrode method involved applying traction to the tongue ten or twelve times a minute, this was popular from the turn of the century up to at least the 1940s, if not later.[70] This method was based on the discovery of certain reflex reactions, and it was found that this caused a reflex gasping reaction. Some clinicians believed that drawing some blood from the umbilical vein to relieve the pressure on the right side of the heart, would relieve the depressant effect of asphyxia on the newborn.[71] Various stimulatory drugs were also popular from the early twentieth century, such as adrenaline and pituitary extract.[72] However, as already mentioned, these will not be discussed in any detail in the thesis.

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O'Donnell, C., A. Gibson, et al. (2006). "Pinching, electrocution, raven's beaks, and positive pressure ventilation: A brief history of neonatal resuscitation." *Archives of Disease in Childhood. Fetal and Neonatal Edition* **91**: F369-373.
DeLee, J. (1913). *The principles and practice of obstetrics, 1st edition*. Philadelphia and London, WB Saunders & Company.
Barton, E. (1915). "The condition of the larynx and trachea in the stillborn infant and its bearing on artificial respiration." *BJOG: An International Journal of Obstetrics and Gynaecology* **27**(3): 138-140.

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O'Donnell, C., A. Gibson, et al. (2006). "Pinching, electrocution, raven's beaks, and positive pressure ventilation: A brief history of neonatal resuscitation." *Archives of Disease in Childhood. Fetal and Neonatal Edition* **91**: F369-373.
Williams, J. (1906). *Obstetrics: A textbook for the use of students and practitioners.* New York, D Appleton and Company,
Sheldon, W. (1936). *Diseases of infancy and childhood*. London, J & A Churchill Ltd.
Brothers, A. (1896). *Infantile mortality during childbirth and its prevention*. Philadelphia, P Blaikston, Son & Co.

71

DeLee, J. (1913). *The principles and practice of obstetrics, 1st edition*. Philadelphia and London, WB Saunders & Company,
Parsons, L. and S. Barling (1933). *Diseases of infancy and childhood*. London, Oxford University Press & Humphrey Milford.

72

Brothers, A. (1896). *Infantile mortality during childbirth and its prevention*. Philadelphia, P Blaikston, Son & Co, As has been mentioned, these techniques were often used in combination, as clinicians became increasingly desperate to resuscitate the dying infant. This desperation and the lack of a distinct protocol is illustrated in the following quote from a letter to the editor of the *Lancet*, from an obstetrician in 1894:

> The child when born was to all appearances dead. The face was pale, the limbs flaccid, and there was no appreciable cardiac action. The cord was at once ligatured and the child separated from the mother. There appeared to be complete cessation of respiration. The alternate immersion of the child, first into very hot and then into very cold water, half a dozen times proved to be of no avail. Insufflation of the lungs was next resorted to, by means of a catheter guided into the glottis, and air was gently blown into the lungs, with alternate compression of the thorax, with a view to expel the air. This was persevered in for about three-quarters of an hour, but proved fruitless. Silvester's and Schultze's methods of artificial respiration were then adopted , and given a fair trial for more than an hour, and this time the treatment met with some success. The child made one or two feeble and gasping efforts at respiration. Brandy was placed on the tongue and also applied to the chest and regions over the heart; at length the child began to whine, while the stethoscope revealed very feeble cardiac beats. The catheter was again introduced into the glottis, and the lungs were insufflated for another half hour. The child was once more alternately immersed in hot and cold water, and it started screaming at the second immersion. It was then wrapped in a blanket, a few more attempts at artificial respiration having thoroughly established the function. On auscultation the heart was now heard to beat regularly and distinctly.[73]

Tellingly these techniques were mainly to be found in textbooks of obstetrics, and were advocated by obstetricians. However as paediatricians and other specialists became increasingly concerned with the care of the newborn this gradually changed from the late 1920s through to a period of more rapid development in the 1960s.

'Save the babies'[74]: the wider context of the early twentieth century

Before going on to discuss the changes which occurred from the late 1920s, with new sets of actors taking an interest in the asphyxiated newborn, and contributing

DeLee, J. (1913). *The principles and practice of obstetrics, 1st edition*. Philadelphia and London, WB Saunders & Company.

73

Tarachand, N. (1894). "A case of asphyxia neonatorum." *Lancet* **2**: 1277.

74 This was a slogan popularized by infant welfare activists in both Britain and the USA during the late nineteenth and early twentieth century.

to the transformation of its care, it will be useful to understand some other social changes which influenced these changes in the medical care of the newborn and physiological understanding of the newborn more generally and asphyxia neonatorum specifically.

By the turn of the twentieth century three important statistical trends were noted in western countries: a high infant mortality rate, high maternal mortality rate, and a falling birth rate.[75] These trends were also accompanied by concerns over 'national efficiency'. As Richard Meckel has argued:

> Conceptually shaped by emerging concepts of political economy and by the convergence of several strains of post-Darwinian evolutionary theory, alarm over the quantity and quality of population found specific expression in concern over falling birth-rates and was dramatized by increasingly high rates of rejection for military recruits and by the publication of statistics purporting to show rising mental and physical degeneracy.[76]

These concerns surfaced first in France after its defeat during the Franco-Prussian war, and then later in Britain during the Boer War, and were again emphasized during the First World War in Europe and America.[77] This in turn led to the formation of national and international organizations and committees to address the problem and a vast array of interventions in medical practice, public health policy and social movements, in an attempt to address these issues.[78]

From the middle of the nineteenth century there was a growing awareness of high infant mortality rates in both Europe and America. By the late nineteenth century these concerns had begun to translate into the establishment of infant

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Loudon, I. (1992). *Death in childbirth. An international study of maternal care and maternal mortality, 1800 - 1950.* Oxford, Clarendon Press,
Marland, H. (2003). "Childbirth and maternity". in *Companion to medicine in the twentieth century*. J. Pickstone and R. Cooter (Ed.). London & New York, Routledge**:** p559-574.

76

Meckel, R. (1990). *Save the babies. American public health reform and the prevention of infant mortality, 1850-1929*. Baltimore & London, Johns Hopkins University Press. p101.

77

Ibid. p102.
Loudon, I. (1992). *Death in childbirth. An international study of maternal care and maternal mortality, 1800 - 1950.* Oxford, Clarendon Press. p207.
Cone, T. (1985). *History of the care and feeding of the premature infant*. Boston/Toronto, Little, Brown and Company. p15.

78

Meckel, R. (1990). *Save the babies. American public health reform and the prevention of infant mortality, 1850-1929*. Baltimore & London, Johns Hopkins University Press. p106.

dispensaries and clinics and children's hospitals and were also linked to the emergence of paediatrics as a distinct medical specialty.[79] Analysis of the infant mortality rates highlighted gastrointestinal infections as a major factor, and this led clinicians to focus on improving infant feeding as a means of tackling infant mortality.[80] The final decades of the nineteenth century and early years of the twentieth century witnessed the establishment of infant welfare movements in Europe, Britain and America and also saw paediatricians investing lots of time researching artificial feeding, and led to the setting up of milk depots for impoverished mothers and babies.[81] The example of Pierre Budin in Paris, demonstrated that breastfeeding was in fact better for newborns, and his 'Consulations de nourrisons' were shown to have a direct effect on infant mortality.[82]

The concerns over high maternal mortality towards the end of the nineteenth century contributed to the emergence of reformers intent on improving obstetrical care. In Britain this translated into the Maternity and Welfare Act 1918, the Midwives Acts of 1902 and 1936, the establishment of philanthropic organizations, and the Royal College of Obstetricians and Gynaecologists which led to improvements in maternity care.[83] At the same time infant welfare reformers began to focus on the education of mothers in the care of the newborn, with an emphasis on feeding and hygiene.[84]

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79 Ibid. p46.

80 Ibid. p48.
Marks, L. (1992). "Mothers, babies and hospitals: 'The London' and the provision of maternity care in east London, 1870-1939." In *Women and children first: Internation maternal and infant welfare, 1870-1945*. V. Fildes, S. Marks et al (Eds.). London & New York, Routledge: 48-73.

81 Ibid.

82 Ibid. p92.

83 Loudon, I. (1992). *Death in childbirth. An international study of maternal care and maternal mortality, 1800 - 1950.* Oxford, Clarendon Press.
Marks, L. (1992). "Mothers, babies and hospitals: 'The London' and the provision of maternity care in east London, 1870-1939." In *Women and children first: Internation maternal and infant welfare, 1870-1945*. V. Fildes, S. Marks et al (Eds.). London & New York, Routledge: 48-73.
Williams, A. (1997). *Women & childbirth in the twentieth century. A history of the National Birthday Trust Fund 1928-93.* Gloucestershire, Sutton Publishing. p1.

84 Meckel, R. (1990). *Save the babies. American public health reform and the prevention of infant mortality, 1850-1929*. Baltimore & London, Johns Hopkins University Press. p100.

During the 1930s, with the introduction of sulphonamides to treat puerperal fever and a number of other significant factors, including the standardisation of midwifery and improved social conditions, maternal mortality began to decline rapidly.[85] However, neonatal mortality had remained high, and its significance was beginning to be uncovered during the 1920s. Although post-neonatal mortality was falling, neonatal mortality remained consistently high, and was becoming the dominant grouping in infant mortality rates. These concerns were also echoed in the US, and led to some early attempts on both sides of the Atlantic to provide more specialized medical care for newborns during the interwar years, particularly for premature infants. This led to the establishment of the first modern premature infant stations and nurseries, such as Julius Hess' infant station at the Sarah Morris Hospital, Chicago, which opened in 1922, and Victoria Crosse's premature infant nursery, which was opened in Birmingham in 1931.[86] However, these changes were limited and really only translated into a small number of individual units. It was within this context of a growing realisation of the cost of neonatal mortality that the first new group of actors, the physiologists, began to centre their gaze on the newborn.

The birth of fetal and neonatal physiology, 1927-1946

From the early decades of the twentieth century some leading physiologists, in particular the British physiologist John Scott Haldane (1860-1936), had become increasingly interested in respiratory physiology, in part influenced by aviation research and the effects of gas poisoning during the First World War and also high-altitude physiology linked to mountaineering. By the 1920s some of those interested in respiratory physiology in Britain and America began to direct their attention towards the fetus and newborn, as it became apparent that the mechanisms surrounding the first breath and the causes of asphyxia neonatorum were still elusive. This novel interest in the fetus and newborn was also influenced

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Marland, H. (2003). "Childbirth and maternity". in *Companion to medicine in the twentieth century*. J. Pickstone and R. Cooter (Ed.). London & New York, Routledge**:** p559-574.
Loudon, I. (1992). *Death in childbirth. An international study of maternal care and maternal mortality, 1800 - 1950.* Oxford, Clarendon Press. p255.

86

Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust. p4,
Dunn, P. (2001). "Julius Hess, M.D. (1876-1955) and the premature infant." *Archives of Disease in Childhood, Fetal and Neonatal Edition* **85**:142.

by the research of the Finnish paediatrician Arvo Ylppö (1887-1992) who had conducted research on the physiology and pathology of the neonate in Berlin between 1912 and 1920.[87] Ylppö was one of the earliest investigators to conduct physiological research on the newborn with a particular emphasis on premature infants.[88]

Ylppö's work influenced three of the most important figures in this field from Britain and the United States, Yandell Henderson (1873-1944), Nicholson J Eastman (1895-1973), and Sir Joseph Barcroft (1872-1947). This section will begin by outlining the research they conducted on fetal and neonatal physiology relating to respiration and asphyxia, during the period 1927-1946 and will discuss some of the interesting themes which emerged. The following section will then examine the impact, if any, this research had on clinical practice, specifically on the treatment of asphyxia neonatorum, during the same period.

Some of the interesting themes which will emerge in this section will include: the gradual realisation that adult physiological knowledge could not be directly applied to the newborn; a growing awareness that the newborn was physiologically unique as it was in a transition phase, moving from life as a fetus *in utero* to one as an autonomous being, which involved massive physiological changes; physiologists also began to recognize, as they attempted to define the 'normal' state of the fetus and newborn, that conditions considered to be 'pathological' in adults, were in fact 'normal' in the newborn and fetus. Although many theories about the physiology of both the fetus and newborn had existed prior to the 1920s, they were mainly inferred from adult physiology and lacked any clinical or physiological evidence from empirical research. The 1920s witnessed the first real clinical and physiological research on the subject.

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Cone, T. (1985). *History of the care and feeding of the premature infant*. Boston/Toronto, Little, Brown and Company. p45.
Ballowitz, L. (1980). "Avro Ylppö" in *Historical review and recent advances in neonatal and perinatal medicine, vol. 1.* G. Smith and D. Vidyasagar (Eds.). Illinois, Mead Johnson Nutrition Division: ix-xi.

88

Ballowitz, L. (1980). "Avro Ylppö" in *Historical review and recent advances in neonatal and perinatal medicine, vol. 1.* G. Smith and D. Vidyasagar (Eds.). Illinois, Mead Johnson Nutrition Division: ix-xi.
Ibid.

Sir Joseph Barcroft started a research programme in the Cambridge Physiological Laboratory in 1897, and remained there throughout most of his life. His research interests were varied in his early career, but one of his significant collaborations was with JS Haldane, with whom he examined blood-gas analysis.[89] This early work on blood-gases developed into his lifelong interest in haemoglobin and its relationship with oxygen. One of his most important breakthroughs came in 1914 when he published the oxygen dissociation curve of haemoglobin.[90] Throughout the First World War he was enlisted to work on the medical and physiological effects of gas poisoning at the government labs at Porton Down, where he also developed an interest in high-altitude physiology.[91] After the war Barcroft continued his research on the physiological effects of high altitudes, and studied the adaptation which mountaineers and people living at high altitudes underwent in response to the lower oxygen environment. A lot of this research was published in the second edition of his book *The Respiratory Function of the Blood*. By 1925 he had come to occupy the chair in physiology at the University of Cambridge.

By the early 1930s Barcroft had begun a new phase of research, undeterred by the fact that he was almost 60 years old. He had also forged a productive partnership with the American physiologist Donald Barron.[92] His interest in haemoglobin had led to a series of publications on blood depots in the body, such as the liver and placenta. This in turn led to an interest in the interactions between the placenta and fetus, and mammalian fetal physiology more generally.[93] During the 1930s and 1940s, until his death, Barcroft and his associates produced vast numbers of publications on mammalian fetal physiology, and more significantly, these had a major impact on the understanding of fetal respiration and the

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West, J. (2004). “Barcroft, Sir Joseph (1872-1947)”, *Oxford Dictionay of National Biography,* Oxford University Press. http://www.oxforddnb.com/view/article/30580?docPos=3

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Barcroft, J. (1914). *The respiratory function of the blood*. Cambridge, Cambridge University Press.

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West, J. (2004). “Barcroft, Sir Joseph (1872-1947)”, *Oxford Dictionay of National Biography,* Oxford University Press. http://www.oxforddnb.com/view/article/30580?docPos=3

92

Donald H Barron (1905-1993) was an American physiologist who formed a strong collaborative relationship with Barcroft during the interwar years. However, this very successful and productive partnership was cut short with the advent of World War II, when Barron was forced to return to America, and took up a post at Yale University. Barron would later become an important figure in the neonatal network which is described in chapter 5.

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Franklin, K. (1953). *Joseph Barcroft 1872-1947.* Oxford, Blackwell Scientific Publishing. p203..

initiation of respiration at birth in both mammals and humans. The majority of Barcroft's research was conducted on animals, although in later years he did begin to observe human newborns and draw comparisons between the two.

The second significant figure in this period, with an interest in the respiratory physiology of the asphyxiated newborn, was Yandell Henderson (1873-1944). Henderson was a physiologist from Yale University who had developed an interest in cardio-respiratory physiology whilst also working with JS Haldane at the University of Oxford before the First World War. Like his contemporary Barcroft, he was also interested in high altitude physiology, although, unlike Barcroft, Henderson was an exponent of applied physiology. His work during the 1910s and 1920s mainly centred around acclimatisation, aviation medicine, resuscitation after carbon monoxide poisoning, and also anaesthesia, which he hoped to apply directly to clinical problems. It was his work on resuscitation of victims of carbon monoxide poisoning that led Henderson to attempt to apply the same treatments to the asphyxiated newborn during the late 1920s.

The third principal figure in fetal and neonatal physiology, with regards to asphyxia neonatorum, was Nicholson J Eastman. Although strictly speaking Eastman was not a physiologist, but in fact the Chief of Obstetrics at Johns Hopkins Hospital, his clinical and physiological research during the 1920s and 1930s produced critical physiological information on fetal and neonatal respiration.

Throughout the period these three figures were greatly influenced by each other's work, and in turn influenced others interested in the subject. All three came to work on neonatal and fetal respiration for slightly different reasons, but were equally influenced by growing concerns over high infant and specifically neonatal mortality rates, which have already been discussed. For Barcroft his main motivation would appear to have been scientific curiosity, as he lamented several times about the 'meagre knowledge' which had existed before the 1930s on fetal and neonatal physiology.[94] Henderson was motivated both by the alarmingly high newborn mortality in the US, as well as an eagerness to apply his resuscitation technique to other forms of asphyxia, beyond carbon monoxide poisoning.[95] Eastman, as an

94 Barcroft, J. (1941). "Four phases of birth." *Lancet* **2**: 91-95.

95 Henderson, Y. (1928). "The prevention and treatment of asphyxia in the new-born." *JAMA* **90**(8): 383-386.

obstetrician, was most obviously stimulated by his own experience of helplessness when treating asphyxiated newborns, as well as being influenced by the research of both Henderson and Barcroft on the respiratory function of blood.[96] Each also took a different approach to his research. As mentioned, Barcroft worked solely on animals and only later began to observe human infants. Henderson, although also a physiologist by training, was a strong advocate of applied physiology, so his ideas combined animal research and clinical study. Eastman, as an obstetrician, conducted his research on clinical cases.

Yandell Henderson: applying physiology to the resuscitation of the newborn

With the growing interest in the biochemistry of the blood and specifically in regards to asphyxia and respiration, there was a growing awareness that the onset of respiration could be conditioned by chemical factors.[97] This was in part due to the elucidation of the chemical factors which influenced adult respiration. Yandell Henderson was interested in asphyxia generally and developed the inhalatory method through his work on adults.[98] He believed that carbon dioxide was the major respiratory stimulant, originally advocating the use of carbon dioxide therapeutically after anaesthesia to help to re-establish normal respiration. In other forms of asphyxia, such as carbon monoxide poisoning, Henderson believed that it was a lack of carbon dioxide, and therefore lack of respiratory stimulus, which was the most significant factor. He therefore advocated the inhalatory method of resuscitation, using high concentrations of carbon dioxide given via a face mask, as a resuscitation technique. By the late 1920s, Henderson was beginning to draw parallels between the carbon monoxide poisoned adult and the asphyxiated newborn.

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Eastman, N. (1930). "Fetal blood studies i. The oxygen relationship of umbilical cord blood and birth." *Bulletin of the Johns Hopkins Hospital* **47**(4): 221-230.

97

Eastman, N. (1932). "Foetal blood studies iii.The chemical nature of asphyxia neonatorum and its bearing on certain practical problems." *Bulletin of the Johns Hopkins Hospital* **50**(1): 39-50.p39.

98

Henderson, Y., H. Haggard, et al. (1920). "The therapeutic use of carbon dioxide after anesthesia and operation." *JAMA* **74**(12): 783-786.

In 1928 Henderson published an article in *JAMA*, 'The prevention and treatment of asphyxia in the new-born'.[99] He was strongly influenced by the alarmingly high neonatal mortality rates in America during the 1920s associated with asphyxia in the newborn. He commented that:

> The first quarter of an hour after birth is the most dangerous period of life. Its mortality is as great as that of any subsequent month. No single discovery in medical science or improvement in practice could do more to save lives than would measures to avoid the losses that now occur within a few minutes after birth.[100]

Henderson was influenced by his research on adults suffering from asphyxia, and using applied physiology, argued that asphyxia should be treated with inhalation of carbon dioxide mixed in oxygen.[101] Henderson believed that the respiratory centre should be stimulated chemically by carbon dioxide, and recommended the use of a mask inhalator, which was attached to the gas cylinder via a manometer which controlled the gas pressure (see figure 3).[102]

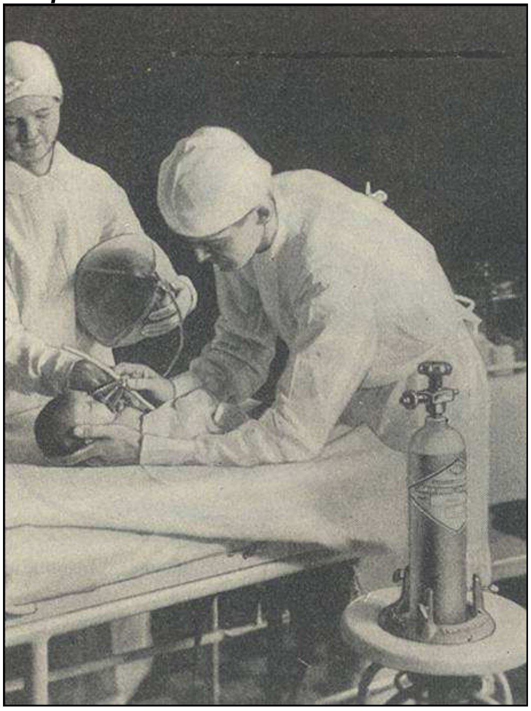
99 Henderson, Y. (1928). "The prevention and treatment of asphyxia in the new-born." *JAMA* **90**(8): 383-386.

100 Ibid. p383.

101 Ibid. p384.

102 Ibid. p386.

Figure 3. Henderson's Inhalatory Method. Image taken from Henderson (1938) *Adventures in Respiration.*



Nicholson J Eastman's 'Foetal Blood Studies'

Nicholson J Eastman, concerned by his experience of treating asphyxiated babies unsuccessfully, was interested in whether hypercarbia [high carbon dioxide levels] or hypoxia [low oxygen levels] was responsible for the initiation of respiration at birth, and published a series of five articles from 1930, which traced his investigations on the subject.[103] In part he was stimulated by Henderson's claims that hypercarbia was the main respiratory stimulant, which Eastman felt lacked any real scientific evidence in relation to the newborn.

In the first article of his series of 'Foetal Blood Studies', Eastman examined the oxygen relationships of umbilical cord blood at birth.[104] He began by explaining that he intended to investigate the components of fetal blood which might be involved with the onset of respiration at birth and commented that:

> While such phenomena as the initiation of breathing, the apnea of intra-uterine life and the clinical syndrome of asphyxia neonatorum, have been explained by various hypotheses, these theories have never been

103 Goldstein, P. (1980). "Birth asphyxia". in *Historical review and recent advances in neonatal and perinatal medicine*. G. Smith and D. Vidyasagar (Ed.). Illinois, Mead Johnson Nutritional Division. **vol.1:** 177-184.

104 Eastman, N. (1930). "Fetal blood studies i. The oxygen relationship of umbilical cord blood and birth." *Bulletin of the Johns Hopkins Hospital* **47**(4): 221-230.

> supplemented by studies of the foetal blood, - a fact that seems particularly remarkable when one recalls the many and fruitful blood chemical investigations that have dealt with the regulation of respiration in the adult … In view of the chemical nature of the respiratory control in adults, it appears altogether probable that a considerable number of these unexplained deaths [of newborns] result from chemical changes in the foetal blood incident in labour … [105]

Eastman conducted his studies on 16 clinical cases, from which he took samples of umbilical blood before the onset of respiration. He found that the fetal blood had a higher capacity for oxygen than maternal blood and argued that this must be due to acclimatization to a low oxygen environment, akin to that found in adults living at high altitudes who developed a higher amount of haemoglobin to compensate, which had been demonstrated by Haldane, Barcroft and Henderson.[106] Eastman concluded that:

> The full term foetus in utero must exist in a state of considerable cyanosis. It must not be inferred from these findings, however, that the foetus in utero normally suffers from oxygen want, since the amount of oxygen lost by the umbilical vein blood in its passage through the foetus, would seem to be plentiful for an organism resting in a dormant state in a medium at constant body temperature.[107]

In the second of the series of five ‘Foetal Blood Studies’, published in 1932, Eastman measured lactate in the umbilical cord of 24 infants, 7 of which had birth asphyxia.[108] As Goldstein has described:

> … [Eastman] showed the maternal-fetal relationships and indicated that this was likely a measure of mild oxygen deficiency. He stated that the absence of hyperlactatemia demonstrated fetal oxygen adequacy.[109]

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105 Ibid. p221.

106 Ibid. p228.

107 Ibid. p229.

108 Eastman, N. (1931). "Fetal blood studies ii. The lactic acid content of umbilical cord blood under various conditions." *Bulletin of the Johns Hopkins Hospital* **48**: 261-268.

109 Goldstein, P. (1980). "Birth asphyxia". in *Historical review and recent advances in neonatal and perinatal medicine*. G. Smith and D. Vidyasagar (Ed.). Illinois, Mead Johnson Nutritional Division. **vol.1:** 177-184. p179

For the first time Eastman began to realise that the hypoxia found in the fetus, which may have been considered pathological in adults, was in fact normal in the fetus. As the fetus was in a dormant state, it actually had adequate oxygen.

In the third article in his series Eastman 'demonstrated that neonatal acidosis accompanies asphyxia'.[110] Eastman was influenced by Schmidt's 1928 'reversal' theory, which suggested that after prolonged oxygen deprivation with acidemia and hypercarbia, cerebral cells, including the respiratory centre, could no longer respond to low oxygen and, rather than stimulating increased respiratory activity, respiratory depression ensued.[111] Eastman also postulated, from this pathophysiologic observations, that the well known ominous process of asphyxia pallida equalled circulatory failure and he concluded that neither high carbon dioxide nor low oxygen were the primary initiators of respiration.[112]

He argued that:

> The various chemical theories which have been advanced to account for the phenomenon [of the first breath] have not been based on well attested facts of foetal physiology, but have been chiefly inferential in character. For instance, the view that the onset of breathing is due to an increased carbon dioxide tension in the blood of the infant, although quite plausible, has not been supplemented by studies of the actual tension of this gas in foetal blood; similarly, the explanation of intra-uterine apnea on the basis of a low carbon dioxide tension is without factual substantiation.[113]

Eastman challenged Henderson's research, arguing that he had based his theory on physiological research on adults with carbon monoxide poisoning and not on asphyxiated newborns.[114] Eastman further pointed out that the clincians Kane and Kreiselman had performed direct studies on the blood of asphyxiated babies, and they found that inhalation of oxygen was as efficacious as carbon dioxide in

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110 Ibid. p179

111 Ibid p180

112 Ibid p180

113 Eastman, N. (1932). "Foetal blood studies iii.The chemical nature of asphyxia neonatorum and its bearing on certain practical problems." *Bulletin of the Johns Hopkins Hospital* **50**(1): 39-50. p39-40.

114 Ibid. p40.

resuscitating babies. Kane and Kreiselman had shown that the carbon dioxide content of the blood of the newborn was consistently high and that the amount of this gas increased with the degree of asphyxia. They had concluded, therefore, 'that the use of carbon dioxide as a resuscitating agent is contraindicated'.[115] Here again Eastman was beginning to recognize the physiological uniqueness of the newborn. This theme emerged more strongly throughout the 1930s.

Eastman decided to study the carbon dioxide content and tension and the hydrogen ion concentration of the fetal blood in normal and asphyxiated newborns. He claimed that his research had allowed him to present 'certain definite conclusions' regarding the treatment of asphyxia neonatorum:[116]

> 1. Since the tension of carbon dioxide in the blood of asphyxiated infants is usually almost twice that found in normal babies, the use of this gas as a resuscitating agent seems to us superfluous and possibly harmful … [and it] may tend to intensify an already existing acidosis …
>
> 2. Since the oxygen content of the blood in asphyxia neonatorum is so low … it seems altogether likely, in view of the experimental work of Schmidt, that the usual forms of stimulation (including slapping, bathing and carbon dioxide inhalation) produce depression rather than excitation of the respiratory center and may even result in irreparable damage to the brain cells.[117]

Eastman concluded that:

> There seems to be only one urgent indication in the treatment of asphyxia neonatorum, and that is to introduce oxygen into the circulating blood of the infant. Whether this is effected by manual artificial respiration, by mouth to mouth breathing, or by some form of apparatus such as the Drinker respirator, seems to us of minor importance, so long as the air passages have been carefully cleared of mucus and a constant supply of oxygen (or air) is maintained into the pulmonary alveoli.[118]

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[115] Ibid. p40.

[116] Ibid. p49.

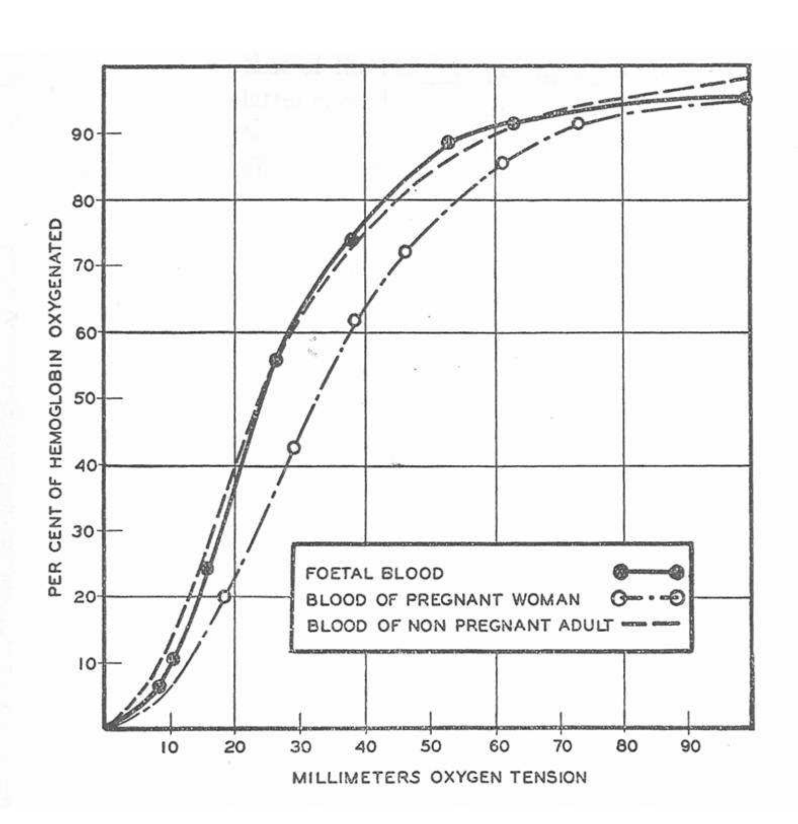
[117] Ibid. p49.

[118] Ibid. p49

Although he conceded that the exact cause of the onset of respiration remained obscure, he was sure that the high carbon dioxide tension could only be explained by a de-sensitizing of the respiratory centre due to asphyxia.[119]

Building on the work of Barcroft, who had published the oxygen dissociation curve of adult haemoglobin in 1914, Eastman discovered that during pregnancy the maternal dissociation curve shifted right, whereas the fetal haemoglobin had a curve which lay to the left of the normal (see figure 4).[120] This research was published in 'Foetal Blood Studies IV', in 1933.This meant that the maternal blood gave up oxygen more easily and the fetal blood had a higher affinity for oxygen. He commented that 'from the view of placental interchange, therefore, the dissociation relationships of these two bloods are ideal'.[121]

Figure 4. Eastman's oxygen dissociation curve for fetal and maternal haemoglobin. Taken from Eastman (1933) 'Foetal Blood Studies IV', *Bulletin of the Johns Hopkins Hospital* v53, p246-254.



119 Ibid. p49

120 Eastman, N., E. Ceiling, et al. (1933). "Foetal blood studies iv. The oxygen and carbon dioxide dissociation curves of foetal blood." *Bulletin of the Johns Hopkins Hospital* **53**(5): 246-254.

121 Ibid. p250.

With regards to the carbon-dioxide dissociation curves of maternal and fetal blood, a similarly advantageous change was found. The fetal carbon dioxide curve lay to the right of the normal, whereas the pregnant women's curve was shifted left.[122] This meant that the maternal blood had a higher affinity for the gas and the fetal blood gave it up more readily, again conducive to placental transfer from fetal to maternal circulation. Eastman's research on the fetal and maternal haemoglobin was very important for building the picture of the 'normal' fetus and newborn, against which the pathological could be measured and identified.

Most significant of all, because of chance accidents, Eastman had been able to measure the carbon-dioxide tension of fetal blood at birth in seven cases. The newborns had taken their first breath just as the clamps were applied to their umbilical cords.[123] He found that the samples were 'scattered throughout the entire physiological range', and that respiration appeared to have been established equally well regardless of carbon dioxide tension. This led him to conclude in 1933 that 'some factor other than blood carbon-dioxide tension is the dominant one in the onset of respiration at birth', which directly opposed Henderson's research.[124]

Joseph Barcroft ventures into neonatal physiology

As has been mentioned, Barcroft had begun his fetal and neonatal research, in Cambridge, in 1930. However, he did not present his preliminary research findings until 1933 at the American Association of Science Annual Meeting.[125] It was a resumé of work carried out over the previous three years by his research group.[126] Like Eastman, Barcroft and his associates were searching for the 'normal' state of the fetus and newborn. Their research, again like Eastman's, began to discover that states considered pathological in an adult, were found to be normal in the fetus and newborn. This research contributed to the growing sense that the newborn was distinct physiologically from older children and the adult.

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122 Ibid. p251.

123 Ibid. p253.

124 Ibid. p253.

125 Barcroft, J. (1933). "The conditions of foetal respiration." *Lancet* **2**: 1021-1024.

126 Franklin, K. (1953). *Joseph Barcroft 1872-1947.* Oxford, Blackwell Scientific Publishing. p207.

Barcroft's interest in high altitude physiology was apparent in his research, as he drew parallels between the developing fetus and mountaineers. This was the first time he used his famous analogy of 'Everest in Utero', when he compared the fetus to a climber ascending a mountain with a continually falling oxygen saturation in the environment. He commented:

> It is not without interest whilst studying embryonic respiration to keep one eye upon the mountain climber, in the economy of whose blood two principal changes have been noted – an increase in the haemoglobin present, and a shift in the oxygen dissociation curve in the sense of greater affinity of the blood for oxygen.[127]

He had completed his studies on goats. At this point, however, the details were still obscure. Like Mount Everest, the mammalian fetus and newborn were viewed by Barcroft as something which needed to be conquered.

In 1934 Barcroft presented his research on the fetal goat at the British Association Symposium in Aberdeen.[128] His findings were mainly in agreement with Eastman's fetal blood studies on human infants. Barcroft's further key contribution to fetal physiology was that:

> As pregnancy advances, the [oxygen] content [of fetal haemoglobin] sinks until at term the blood is almost denuded of oxygen. Even so, the oxygen in the foetal blood feeding the foetal organs does not reach a level as high as would be found in arteries of a man on the top of Mount Everest; it is doubtful indeed whether the foetal oxygen level would be enough to maintain consciousness in the born animal. The foetus, however, appears to be better off, in that the oxygen consumption of its tissues, per unit weight, may be only about a third of the oxygen consumption per unit weight after birth.[129]

By the mid-1930s Barcroft had identified the growing inhibition, effected by the higher centres of the nervous system, of the reflexes elicitable in earlier stages of intrauterine life; he grasped the differential distribution of the better oxygenated and the poorly oxygenated blood coming from the fetal heart; and he was getting

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127 Barcroft, J. (1933). "The conditions of foetal respiration." *Lancet* **2**: 1021-1024.

128 Franklin, K. (1953). *Joseph Barcroft 1872-1947.* Oxford, Blackwell Scientific Publishing p216.

129 Ibid. p216.

interested in fetal by-passes, namely, the ductus arteriosus, which was destined to be a special area of research in the future.[130]

On a trip to the US in 1936 Barcroft was interviewed by a reporter in Buffalo, and was reported to have commented that:

> One has found out that a great many of the movements of life, supposed to appear after birth, really can be seen and estimated long before. Just as a steamer's engines are tried out before she sails, so vital movements, such as respiration, are practiced long before birth. That really sums it up.[131]

This quote highlights a new stage in his fetal research, when he was beginning to study the movements of the fetus *in utero,* which will be described in more detail later in this chapter. In the same year Barcroft also retired from his Chair at Cambridge, but he continued his research at the Cambridge laboratories up until his death.

In 1937 the physiologists, F Snyder and M Rosenfeld, from the Department of Obstetrics and Gynecology, Johns Hopkins Hospital, published their research on fetal rabbits.[132] Snyder and Rosenfeld, like Barcroft, had been studying the respiratory movements of the fetus *in utero*, and how it was affected by carbon dioxide and oxygen. Their research findings were contrary to some of the popular theories of the time, including Eastman's research and the belief that the fetus was in a prolonged dormant state in the womb.[133] They concluded that both oxygen-

130 Ibid. p224-225.
The ductus arteriosus and foramen ovale are fetal circulatory by-passes, which essentially allow the fetus to bypass pulmonary circulation. They close after birth to allow blood to circulate through the lungs. The foramen ovale allows blood to pass directly from the left to the right atrium. The ductus arteriosus shunts blood between the pulmonary artery and the aortic arch.

131 Ibid. p243.

132 Snyder, F. and M. Rosenfeld (1937). "Direct observation of intrauterine respiratory movements of the fetus and the role of carbon dioxide and oxygen in their regulation." *American Journal of Physiology* **119**: 153-166.

133 Ibid.

want and low levels of carbon dioxide depressed fetal respiration.[134] However, they argued that an excess of carbon dioxide had no effect on the fetal respiration.[135]

Henderson's continued adventures in respiration

In 1938 Henderson published his book *Adventures in Respiration*.[136] Although it dealt with a variety of different types of asphyxia it laid a particular emphasis on the asphyxiated newborn, which had become a special area of interest for Henderson. It was clear that, by this point, he was heavily influenced by the research findings of both Barcroft and Eastman, as chapters of the book were dedicated to describing the advances made in fetal and neonatal respiratory physiology.[137]

Henderson used the metaphor of a car motor when describing the transition from fetal life to independent existence. The fetus, exhibiting respiratory movements in utero, was like an idling car. At birth, the strong sensory stimuli induced muscle tone and the lungs began to expand as the child breathed. However, the asphyxiated infant was like a stalled motor:

> The motor may be cranked and spun until, in spite of poor carburetion and ignition, a "cough" is induced. The baby likewise may be manhandled, as it formerly commonly was, until a reflex gasp is elicited.[138]

Henderson argued that 'better methods' were now available which allowed resuscitation without the need for 'cranking'.[139] These methods were those of inhalation and insufflation of carbon dioxide and oxygen.

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134 Ibid. p165.

135 Ibid. p165.

136 Henderson, Y. (1938). *Adventures in respiration. Modes of asphyxiation and methods of resuscitation*. London, Bailliere, Tindall & Cox.

137 Ibid. Chapters IX and X discuss the then current understanding of fetal and neonatal physiology, including the initiation of extra-uterine respiration and the causes and physiological effects of asphyxia.

138 Ibid. p166.

139 Ibid.p166.

Henderson maintained that the different forms of asphyxia required different treatments. He therefore recommended two variations on treatment depending on the severity of asphyxia witnessed. For moderate asphyxia, or livida, he relied on his own method of clearing the mouth, pharynx and trachea of mucus and then using a face mask and a small rubber bag connected to a mixture of carbon dioxide and oxygen, to provide short bursts of the gas about 10-15 times per minute. He argued that 'usually a small, but sufficient, part of the lungs is thus inflated; and under the influence of the inhaled gases the baby begins to breathe.'[140] He believed that this method simultaneously relieved the nervous system of anoxia and provided stimulation in the form of carbon dioxide.

However in more severe cases of asphyxia pallida, when the infant was flaccid and the glottis was relaxed, Henderson advocated the administration of the carbon dioxide oxygen mixture via insufflation using the Meltzer-Flagg technique of endotracheal intubation.[141] Although Henderson had accepted that oxygen was also a necessity in newborn resuscitation, as advocated by Barcroft and Eastman, he still argued for the supremacy of carbon dioxide as the respiratory stimulant. He understood that anoxia led to depression of the respiratory centre, and therefore, without sufficient oxygen, carbon dioxide could not be detected and could not act as a respiratory stimulant. While others dismissed carbon dioxide completely, Henderson continued to advocate the use of carbon dioxide, based on his appreciation of its significance as a respiratory stimulant in adults, and also that a rise in carbon dioxide induced a faster response than a fall in oxygen. He stated that 'carbon dioxide strengthens the capacity of the organism to withstand anoxia. In proper dilution … carbon dioxide is a far more effective agent for resuscitation from asphyxia than is pure oxygen.'[142]

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140 Snyder, F. and M. Rosenfeld (1937). "Direct observation of intrauterine respiratory movements of the fetus and the role of carbon dioxide and oxygen in their regulation." *American Journal of Physiology* **119**: 153-166. p185.

141 The Meltzer-Flagg method involved the insertion of an endotracheal tube into the infant's trachea with the aid of a laryngoscope. A reservoir bag attached to a pressurised gas cylinder was then attached to the tube, which was intermittently squeezed to provide intermittent positive pressure insufflation with an oxygen-air mixture. The use of endotracheal intubation with intermittent positive pressure is discussed in more detail over the remaining chapters and an image of the technique can be found on p67.

142 Snyder, F. and M. Rosenfeld (1937). "Direct observation of intrauterine respiratory movements of the fetus and the role of carbon dioxide and oxygen in their regulation." *American Journal of Physiology* **119**: 153-166. p190.

It is clear that Henderson was very aware of the more recent research findings of both Eastman and Barcroft. Henderson had begun to adjust his position slightly to accommodate the advances in physiological research which contradicted his own, with the inclusion of oxygen in his resuscitative gas mixture, rather than carbon dioxide alone.

Barcroft builds the foundations of neonatal physiology, 1938-1946

During the late 1930s Barcroft continued to research the closure of the ductus arteriosus after birth, which he finally visualised using radiography in 1939. This work enhanced his appreciation of the uniqueness of the newborn state, as one of transition. He also began to study other animals to deduce factors which governed the initiation of respiration at birth.[143] However, with the advent of the Second World War, Barcroft was called back to Government research, and his successful partnership with Barron ended.[144] Throughout the war years, with the publication lag, some of their work from the late 1930s continued to be published.

The next phase of Barcroft's fetal research concerned the development of respiratory movements *in utero*. During 1939 he published several articles relating to his study of fetal respiratory movements in sheep.[145] By 1940 Barcroft and his colleagues found parallels with their earlier work on goats having determined the oxygen content and saturation of the blood in the carotid artery and cerebral

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Windle, W. and J. Barcroft (1938). "Some factors governing the initiation of respiration in the chick." *American Journal of Physiology* **121**: 684-691.
Mason, M., J. Kennedy, et al. (1938). "Direct determination of foetal oxygen consumption." *Journal of Physiology* **93**: 21-22.
Barclay, A., J. Barcroft, et al. (1938). "X-ray studies of the closing of the ductus arteriosus." *British Journal of Radiology* **11**: 570-585,
Barcroft, J. and M. Mason (1938). "The atmosphere in which the foetus lives." *Journal of Physiology* **93**: 21-22.

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Franklin, K. (1953). *Joseph Barcroft 1872-1947.* Oxford, Blackwell Scientific Publishing. p269.

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Barcroft, J. (1939). "The intra-uterine development of respiratory effort." *BMJ* **ii**: 986-987,
Barcroft, J., D. Barron, et al. (1939). "The effect of asphyxia on inhibition of respiratory movement in the sheep's foetus." *Journal of Physiology* **96**: 12-13.

venous sinuses and having ‘seen at what level of asphyxia, produced by occlusion of the umbilical cord, respiratory movements were “released”’ in the fetus.[146].

This research was summarised in his 1941 Sharpey-Schafer lecture, given at the University of Edinburgh, which was also published in the *Lancet*.[147] In the paper, ‘The four phases of birth’, Barcroft commented that ‘until the last two or three years little has been added to the meagre knowledge of the physiology of birth possessed by our forefathers’.[148] His research on fetal goats and sheep, which had been conducted from the early 1930s, had led him to define four phases of birth: the change in atmosphere; the transfer of blood from the placenta; alterations in the thoracic circulation; and the first breath.

The first phase was not only a change in the sensory environment, but more importantly a change in the supply of oxygen. Barcroft returned to the analogy of the fetus as a mountaineer ascending Everest, growing inside the uterus with a diminishing oxygen supply relative to demand. However at birth this situation is reversed, as Barcroft commented:

> Within four minutes of birth all this is changed. I well remember the joy with which I ran down the Peak of Teneriffe, prompted by the exhilaration of the inhalation of continually increasing quantities of oxygen … The foetus makes its descent – a far greater one – within four or five minutes, as was shown by a continuous record of the oxygen in its arterial blood as it was subjected to caesarean section.[149]

When he considered the first breath, Barcroft stressed that:

> True it is the first time that air is taken into the lungs, if only because the foetus has never been exposed to air; but the movements responsible for that inhalation have a history which can be traced back to the very first efforts of which the foetus was capable.[150]

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146 Barcroft, J., D. Barron, et al. (1940). "The oxygen supply of the foetal brain of sheep and the effect of asphyxia on foetal respiratory movement." *Journal of Physiology* **97**: 338-346.

147 Barcroft, J. (1941). "Four phases of birth." *Lancet* **2**: 91-95.

148 Ibid. p91.

149 Ibid. p92.

150 Ibid. p94.

As mentioned, his research on fetal sheep, from the late 1930s, had allowed him to track the development of these respiratory movements *in utero*. In sheep this first appeared as a reflex to touch from around the 34th day of gestation. By around the 50th day inhibition of this reflex had developed from the higher centres of the brain. However, asphyxia acted as a depressant on these higher centres and therefore caused the fetus to regain its reflex reaction to touch. At birth:

> [T]he inhibition of the foetus is abolished or reduced by the suspension of the placental circulation; stimulation inevitably occurs and is amplified, as it were, by the heightened sensitivity of the nervous system. Then response takes place. That response is not the old movement in a fluid medium but a gasp which expands and draws air into the lungs; it is the first breath.[151]

Clinically this was a very important paper. Barcroft was suggesting that a mild asphyxia at birth was in fact necessary or ‘normal’, as it depressed the higher brain inhibition of the fetal respiratory movements, which were observed *in utero*. This prompted the reflex gasping reaction in the newborn, which expanded the lungs in the first breath. This again illustrated that the adult pathological state, could be considered the normal state in the newborn.

Further evidence of the physiological uniqueness of the newborn was produced in the research of a group of physiologists from Albany Medical College, New York, which complemented Barcroft’s findings. In 1941, JF Fazekas, FAD Alexander, and HE Himwich published their study on the tolerance to anoxia in adults and newborns of a variety of mammals.[152] They had experimentally induced asphyxia and found that ‘the newborn exhibits an extraordinary tolerance in comparison with the mature animals of the same species’, and ‘the period of tolerance…is not the same in the various species’.[153] They discovered two factors which they believed contributed to this unique ability of the newborn to tolerate anoxia. The first was poikilothermia, an ability to lower its body temperature and therefore reduce its

151 Ibid. p94.

152 Fazekas, J., F. Alexander, et al. (1941). "Tolerance of the newborn to anoxia." *American Journal of Physiology* **134**: 281-287.

153 Ibid. p287.

metabolic demand for oxygen, and secondly an ability to lower its cerebral metabolic rate, which also reduced oxygen demand.[154]

By 1942 Barcroft had begun to relate his research on sheep to actual clinical practice on human newborns, and to spend time at Hammersmith Hospital observing births. These observations had led him to produce the paper, 'The onset of respiration at birth', which was published in the *Lancet*.[155] Barcroft had already defined the sequence of respiratory movements observed in sheep with asphyxia at birth as follows:

> 1) the simple spasm or gasp; 2) the spasm or gasp involving the respiratory muscles outlasted by a respiratory rhythm of shallower respiration; 3) rhythms of shallow respirations which come and go, possibly not preceded by an obvious spasm; 4) the establishment of almost continuous respiration of a normal character. Which appeared would depend on the stringency of the conditions to which the foetus was subjected. The first would be that in which sensation was at its minimum and asphyxia at its maximum, the last at which sensation was at its maximum and asphyxia at its minimum.[156]

He argued that this was also the sequence that should be expected in a human child at birth. He described the sequence observed in human infants, based on his observations at Hammersmith, as follows:

> A human foetus delivered as the result of caesarean section under general anaesthetic … gave a typical picture such as would be given by sheep under the same circumstances. It began life with a series of isolated gasps. The fourth pattern was shown by a baby who began to breathe as soon as his head (which was little if at all cyanosed) emerged and who continued right on. The intermediate patterns were also seen.[157]

Barcroft discussed the work of Eastman and Snyder and Rosenfeld, who had all tried to determine the effect of carbon dioxide on fetal respiratory movements. As has been discussed, these researchers had produced conflicting results from their experiments regarding the role of oxygen want and excessive carbon dioxide.

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154 Ibid. p287.

155 Barcroft, J. (1942). "The onset of respiration at birth." *Lancet* **2**: 117-120.

156 Ibid. p119.

157 Ibid. p119.

From his own work on sheep Barcroft argued that ‘the gasp given by a foetus in poor condition is liberated by oxygen-want, while in a lively foetus both oxygen-want and carbon dioxide excess play a part when the cord is tied’.[158] Pending more information on this subject, however, he concluded that ‘it seems desirable to use the word asphyxia to denote that combination of oxygen want and carbon dioxide excess which is brought about by failure of the placental circulation.’[159] He also emphasised the role played by stimuli to the skin after birth.

Barcroft finished his article by discussing the type of treatment he felt most appropriate for treating the asphyxiated newborn. Contrary to Henderson, Barcroft did not think that carbon dioxide should play a role in resuscitation, as the infant was already overloaded with carbonic acid.[160] Instead, he recommended the use of a stream of oxygen, perhaps mixed with nitrogen, over the nose and mouth of an infant who had had its airways thoroughly cleared of mucus. It is of significance that Barcroft was the second physiologist to directly advocate clinical practice for the treatment of the asphyxiated newborn. After the war physiologists had an increasingly authoritative voice in debates surrounding newborn care, specifically in the case of newborn resuscitation. This theme will be discussed in detail in later.

Barcroft’s time spent at Hammersmith Hospital observing births also led to a publication in the *Cambridge University Medical Society Magazine* in 1942.[161] His article, ‘Respiratory patterns at birth’, described the different ways in which babies commenced pulmonary respiration at birth. Barcroft had identified three obvious patterns: the rhythm, the single prolonged inspiration, and the gasp, and he noted that cyanosis was associated with the second, and markedly so with the third respiratory pattern. Barcroft concluded:

> Speaking generally, we may say that the type of respiration pattern is contingent upon the sensitivity of the nervous system at birth, that this sensitivity is affected either by anaesthetics or by asphyxia, the higher parts being more readily affected than the lower ones; and that the

158 Ibid. p120.

159 Ibid. p120.

160 Ibid. p120.

161 Barcroft, J. (1942). "Respiratory patterns at birth." *Cambridge University Medical Society Magazine* **20**: 6-9.

> more normal the condition of the brain, the earlier respiration will appear, and the more normal will be the respiratory pattern; while the greater the degree of asphyxia, the greater the abolition of function in the higher parts of the brain, and the greater the approximation to gasping in the respiratory pattern.[162]

In 1946, Barcroft compiled his research on fetal and newborn physiology in his book *Researches on Pre-natal Life*.[163] This was originally intended to be the first of two volumes, but Barcroft died a few weeks after its publication.

Another important book, *The Physiology of the Newborn Infant*, had been published in 1945 by Clement Smith (1901-1988), who was Professor of Paediatrics at Harvard University.[164] The appearance of both these texts marked an important phase in neonatal care. They set the fetus and newborn up as a unique subject, which required more study, and also contributed to the development of the sub-specialty of neonatology which began to emerge in the 1950s.

Analysis of the development of fetal and newborn physiology from the 1920s through to the 1940s illustrates a gradual shift in the conception of the asphyxiated newborn. Physiologists initially considered the asphyxiated newborn to possess similar characteristics to the asphyxiated adult, and therefore be responsive to the same treatment. However as they began to study both the fetus and newborn they realised that the newborn was physiologically distinct from older children and adults.

Importantly Barcroft's research began to highlight the massive physiological changes and adaptations which the newborn underwent within the first few minutes, hours and days of life outside the womb, as it made the transition from fetus to infant, as an autonomous, independent being; significantly the change from dependence on the placenta for respiration to pulmonary respiration.

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162 Ibid. p9

163 Barcroft, J. (1946). *Researches on pre-natal life*. Oxford, Blackwell Scientific Publications.

164 Smith, C. (1945). *The physiology of the newborn infant*. Springfield, Illinois, Charles C. Thomas. Clement Smith became an important figure in the development of neonatology after the war, which will be discussed in chapter 5.

As has been discussed in this section, as physiologists attempted to define the ‘normal’ state of both the fetus and newborn, they made surprising discoveries. They found that many conditions considered to be pathological in the adult, were in fact normal in the newborn and fetus. The expansion of newborn and fetal physiology stimulated a re-evaluation of the diagnosis of pathological asphyxia at birth, as physiologists and clinicians tried to determine which cases actually required medical treatment and active resuscitation.

Resuscitation of the newborn, 1929-1945: A scientific approach?

This section will discuss the impact that the experimental neonatal and fetal physiological research had on clinical practice during the same period. This was achieved through a survey of articles in American and British medical journals and medical textbooks, which discussed the resuscitation of the asphyxiated newborn. These changes were also set within the growing influence of experimental physiology in medicine more generally from the early twentieth century. As has been mentioned in chapter 1, from the late 1900s medical education was undergoing reform in both America and Britain.[165] The early decades of the twentieth century witnessed the emergence of a new breed of clinician who viewed bedside medicine ‘in terms of pathophysiology not simply pathological anatomy’ as physiology replaced anatomy as the science of medicine.[166] Therefore the utilization of neonatal and fetal physiological knowledge by clinicians during the interwar years was not that unusual in light of the wider changes in medicine, but that is not to say that it was unproblematic or unchallenged.

The most obvious effect, which has already been mentioned, was the impact Barcroft’s and Henderson’s work had on the American obstetrician Nicholson J Eastman. Eastman, one of the new breed of clinicians who embraced clinical research, was prompted to conduct biochemical analysis of fetal and newborn blood during the 1930s, and his research findings, which have been discussed,

165 As has been discussed in chapter 1 medical reformers called for the increased involvement of universities in medical schools and the setting up of clinical research departments with the employment of full-time experimental physiologists to educate medical students.

166 Lawrence, C. (1985). “Moderns and ancients: The “new cardiology” in Britain 1880-1930.” *Medical History* **Supp 5**: 1-33.p12.

had a significant impact on the care of the asphyxiated newborn at the time. The development of an interest by clinicians in clinical and basic physiological research is a theme which will become more apparent in later chapters, but it is interesting to note that Eastman was an early example of the 'clinician-scientist', who would come to play an important role in the changes in newborn care which occurred in the decades after the Second World War.[167]

Evidence that the neonatal and fetal physiological research, such as Barcroft's, was interacting with the clinical sphere can be found with the increasing number of publications of this physiological research in medical journals. All three of the key figures mentioned published in leading medical journals, such as *JAMA*, the *Lancet* and the *Bulletin of the Johns Hopkins Hospital*.[168] Clearly these researchers felt that their neonatal and fetal research was of clinical relevance. Again this also reflects the growing wider appreciation of the importance of experimental physiology to medicine. However, this does not necessarily imply that they were successful in influencing clinical practice.

My analysis of the medical literature suggests that this neonatal and fetal physiological research impacted on the clinical sphere in four ways:

1. It directly motivated clinicians to develop and introduce novel methods based on their understanding of newborn physiology.

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The 'clinician-scientist' was first described in a paper by Nicolson, M. and Smith, D.(1997). 'Science and Clinical Scepticism: The Case of Ralph Stockman and the Glasgow Medical Faculty'. Presented at Science and Technology Dynamics Internal Progress Conference, Amsterdam, September. The term describes 'practitioners who combined a strong interest in laboratory science with a continuing commitment to clinical control of both practice and research' who emerged during the interwar years.

Christopher Lawrence has also described the 'new cardiologists', such as James MacKenzie and Sir Thomas Lewis, who ventured into clinical research during the early twentieth century, who were also clear examples of these clinician-scientists. See: Lawrence, C. (1985).'Moderns and Ancients'. He also described how Thomas Horder adopted experimental physiology during the early twentieth century in:
Lawrence, C. (1999). "A tale of two sciences: Bedside and bench in twentieth-century Britain." *Medical History* **43**: 421-449.

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Some examples of these publications include:
Eastman, N. (1930). "Fetal blood studies i. The oxygen relationship of umbilical cord blood and birth." *Bulletin of the Johns Hopkins Hospital* **47**(4): 221-230,
Barcroft, J. (1933). "The conditions of foetal respiration." *Lancet* **2**: 1021-1024,
Barcroft, J. (1939). "The intra-uterine development of respiratory effort." *BMJ* **ii**: 986-987,
Barcroft, J. (1941). "Four phases of birth." *Lancet* **2**: 91-95.

2. It stimulated a series of reviews of all methods used to treat the asphyxiated newborn, and contributed to an overall evaluation of newborn care.

3. Clinicians began to cite physiological research both to choose and justify their use of different techniques.

4. Clinicians began to distinguish the ‘normal’ and the ‘pathological’ newborn, and this in turn led to discussions concerning how the pathological newborn could be recognized.

The following sections will illustrate, with examples, how these four elements interacted and the resultant decisions which were made.

As has already been discussed in chapter 1 there is still little historical literature on twentieth-century medicine, and so it is difficult to draw wider comparisons with the impact of basic physiological research and physiologists in other medical specialties. However, Christopher Lawrence’s work on the ‘new cardiology’ does echo some of these trends.[169] Lawrence describes how the clinical conception of the heart was changed dramatically during the early twentieth century due to the work of physiologists. Lawrence showed that this changing conception of the heart and experimental physiology led to changes in clinical practice, both in the diagnosis and treatment of heart conditions, during the interwar years.

Steve Sturdy has also described the unique conditions in Britain during WW1 which allowed physiologists to gain access to soilders suffering from gas poisoning and conduct clinical research for the first time.[170] Physiologists challenged the contemporary medical conception of gas poisoning and the wider theory and practice of medicine. They argued that gas poisoning should be treated as oxygen deprivation and therefore supported the use of oxygen therapy. Sturdy argues that the ultimate success of oxygen therapy as a treatment helped to cement the

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169 Lawrence, C. (1985). “Moderns and ancients: The “new cardiology” in Britain 1880-1930.” *Medical History* **Supp 5**: 1-33.

170 Sturdy, S. (1992). "From the trenches to the hospitals at home: Physiologists, clinicians and oxygen therapy." in *Medical innovations in historical perspective*. J. Pickstone (Ed.). Houndsmill, Basingstoke, Macmillan Press Ltd**:** 104-123.

positon of physiologists in the clinical sphere and after the war contributed to the wider changes in medical education and the promotion of clinical science.

Both Stury's and Lawrence's research suggest there was a growing trend for physiologists to research clinical problems during the interwar years. They also provide wider evidence that during the interwar years physiologists and their research were having an impact on clinical practice and medicine more generally. However, this trend was not always embraced by clinicians.

The introduction of 'modern' and 'scientific' resuscitative methods during the interwar years

During the interwar years a number of novel resuscitative methods were introduced for the treatment of asphyxia neonatorum. Three methods in particular were identified at the time as a definite break from past practices: Henderson's inhalatory method; intubation with positive pressure insufflation; and the Drinker negative pressure respirator. These three techniques came to be viewed as representative of a 'modern' and 'scientific' approach to newborn resuscitation at a time when newborn care was accused of lacking a scientific basis and of being empirical in nature.

As a physiologist, Henderson offered the most obviously scientifically-based method of resuscitation. He appears to have been one of the earliest physiologists to directly advocate a role for physiological research in directing the clinical care of the newborn and is perhaps the most visible example of the influence of physiology on clinical care during this period.[171] The fact that a physiologist was advocating a treatment for the asphyxiated newborn was very unusual during this period. As was discussed earlier in this chapter, historically it was the obstetrician or other clinicians who dictated the care of the newborn. Again this was reflective of the growing authority of science and scientists, particularly physiologists, in British and American medicine during the interwar period.

By 1928 Henderson claimed that several obstetricians, encouraged by his research, had begun to use his technique to resuscitate the newborn. However, as

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171 It perhaps unsurprising that Henderson, who had worked alongside the British respiratory

the hospitals did not own the necessary apparatus, they enlisted the help of fire departments, who used resuscitation equipment in cases of carbon monoxide poisoning.[172] Therefore Henderson's technique is a good example of the growing influence of physiologists more generally were having on clinical practice, as described by Lawrence and Sturdy.[173]

Henderson's research and methods also inspired the anaesthetist Paluel Flagg to consider how his own research could be applied to the asphyxiated newborn, and therefore improve the treatment available. Flagg had been introduced to endotracheal intubation by the anaesthetist Chevalier Jackson, of Philadelphia, and had worked under his supervision when developing his laryngoscope for direct vision intubation. Stimulated by Henderson's research, Flagg believed that his technique could be applied to the resuscitation of the newborn infant. He agreed with Henderson that a resuscitation technique should supply a mixture of carbon dioxide and oxygen to the newborn, but felt that Henderson's method of administration could be improved by use of a laryngoscope and endotracheal tube (see figure 5).[174] Although obstetricians had been using various forms of positive pressure ventilation to treat asphyxia neonatorum sporadically for centuries, this was the first time the anaesthetist applied his specific skills to the problem. This method and the role of anaesthetists in the development of newborn resuscitation will be discussed in more detail in chapters 3 and 4.

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physiologists, such as JS Haldane, felt compelled and justified in advocating clinical practice, given the success respiratory physiologists had during WWI.

172 Henderson, Y. (1928). "The prevention and treatment of asphyxia in the new-born." *JAMA* **90**(8): 383-386.

173 Lawrence, C. (1985). "Moderns and ancients: The "new cardiology" in Britain 1880-1930." *Medical History* **Supp 5**: 1-33.
Sturdy, S. (1992). "From the trenches to the hospitals at home: Physiologists, clinicians and oxygen therapy." in *Medical innovations in historical perspective*. J. Pickstone (Ed.). Houndsmill, Basingstoke, Macmillan Press Ltd**:** 104-123.

174 Flagg, P. (1928). "The treatment of asphyxia in the newborn." *JAMA* **91**: 788-791.

Figure 5. Flagg's method of endotracheal intubation and positive pressure insufflation. Image taken from DeLee & Grennhill (1943) The Principles and Practice of Obstetrics

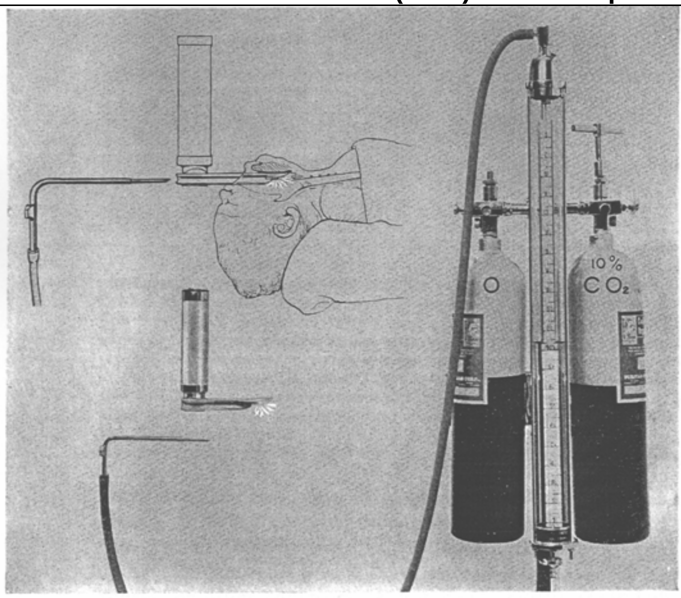


FIG. 648.—FLAGG'S APPARATUS.

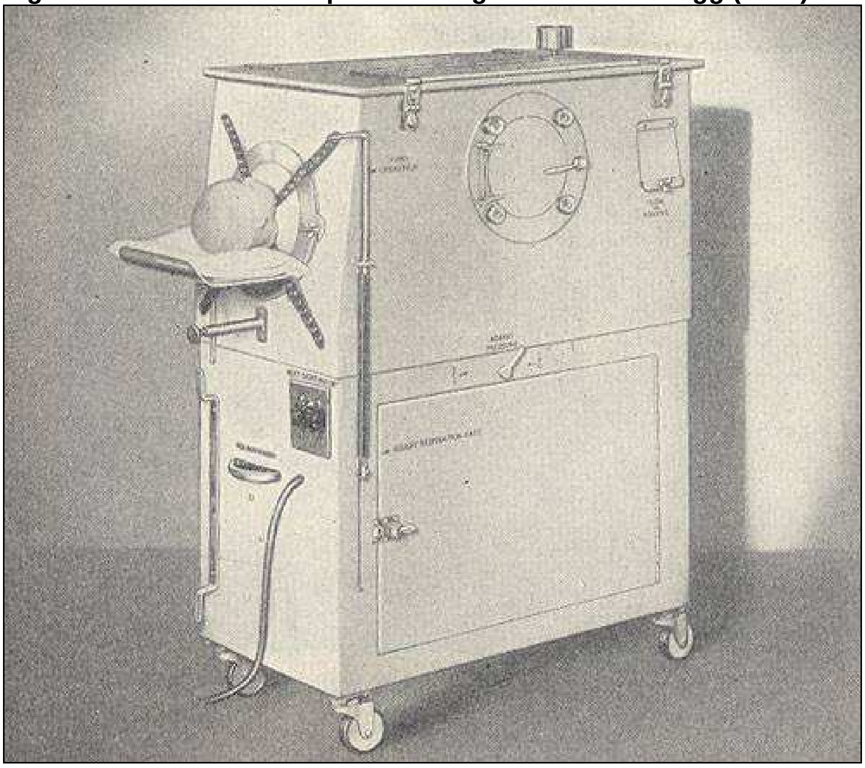
Left—visualization of the larynx, removal of mucus, and direct insufflation of air. Right—the water gauge indicates the pressure of the gases and "blows off" when it passes 10" of water.

Along with Henderson's and Flagg's two novel techniques for treating the asphyxiated newborn, a third fairly new method was also advocated during the late 1920s: the Drinker negative pressure ventilator. It is important to note that all three techniques had their roots in adult care. Henderson's method, which has already been discussed, came from his work on asphyxiated adults. He recommended the use of a face mask to supply carbon dioxide-oxygen mixtures at low pressure, believing that carbon dioxide was the main respiratory stimulant. Flagg's method had its roots in anaesthesia. The third method, a negative pressure ventilator, was first discussed for use in prolonged artificial ventilation in polio cases in 1929 by P Drinker and C McKhann.[175] By 1930 the obstetricians Douglas P Murphy and JV Sessums had begun to use the device to treat asphyxiated newborns.[176].

175 Drinker, P. and C. McKhann (1929). "The use of a new apparatus for the prolonged administration of artificial respiration." *JAMA* **92**(20): 1658-1660. This device has been described on page 12.

176 [Anon] (1931). "New york obstetrical society. Meeting of december 9, 1930." *American Journal of Obstetrics and Gynecology* **31**: 599-603.

Figure 6. The Drinker Respirator. Image taken from Flagg (1944) *The Art of Resuscitation*.



Two Portland-based obstetricians, Albert Mathieu and Albert Holman, were also stimulated by Henderson's research and Flagg's method to publish their own method of newborn resuscitation in *JAMA* in 1929.[177] They were clearly influenced by this new scientific approach to newborn care as they commented that: 'Nowhere in present-day medicine can one see such antiquate, unscientific and haphazard procedures as those practiced in the attempt to induce the new-born child to take its first breath.'[178] As they described their own technique, the influence of newborn physiology was very apparent.

They agreed with Flagg that Henderson's method was 'physiologically impractical' for the newborn, as the infant's:

> … larynx and trachea are weak structures and easily collapsible; their shape is maintained by cartilaginous tissue as yet not ossified, and positive pressure in the pharynx and esophagus easily collapses them, obliterating the patency of their lumen and causing a physiologic obstruction which prevents air or gas from entering the bronchi.[179]

177 Mathieu, A. and A. Holman (1929). "Resuscitation of the asphyxiated new-born." *JAMA* **92**(23): 1917-1918.

178 Ibid. p1917.

179 Ibid. p1917.

Mathieu and Holman stated that the tracheal catheter negated this problem as it could deliver the gas directly to the trachea, preventing gas leaking into the oesophagus and it had the added bonus of being ‘simple, cheap, easy to keep in order and easily accessible at all times’.[180]

However, they suggested a simpler method than Flagg, who had recommended the use of pressurized gas cylinders connected via a rubber bag. Mathieu and Holman instead advocated the use of the operator’s finger as a guide to perform a ‘blind intubation’ and the operator’s own breath, which they argued could deliver appropriate amounts of oxygen and carbon dioxide. This technique was based on an earlier technique described by the famous American obstetrician Joseph De Lee in the late nineteenth century.[181]

Significantly, like Flagg, they believed that most infants would begin spontaneous respirations after simply clearing their airways. Those infants who did not begin spontaneous respirations, or those whose ‘attempts at respiration are evidenced by marked retraction at the costal margins without lessening of the cyanosis’, were the infants which required artificial respiration.[182] This highlights the growing realisation that newborns experienced different forms of asphyxia, and that there was a need to identify those in need of resuscitation.[183]

Unlike Flagg, Mathieu and Holman considered the physiological and pathological basis of their technique in more detail. At the time there was a division of opinion as to the state of the lungs before the first breath, with some believing that they were bathed in amniotic fluid, whilst others believed they were completely atelectatic. Based on pathological evidence, Mathieu and Holman claimed that the

180 Ibid. p1917.

181 DeLee, J. (1913). *The principles and practice of obstetrics, 1st edition*. Philadelphia and London, WB Saunders & Company.

182 Mathieu, A. and A. Holman (1929). "Resuscitation of the asphyxiated new-born." *JAMA* **92**(23): 1917-1918. p1918.

183 This issue, of which infants actually required resuscitation, would become an important one in the debates surrounding newborn resuscitation during the 1950s and 1960s. It will recur throughout the overall period which the thesis examines as it was an issue that was influenced heavily by physiological research after the war.

newborn lungs were in a state of complete atelectasis.[184] They therefore argued that the operator should use gentle puffs to begin with, so as to gradually inflate the newborn's lungs.[185] Physiological studies had shown that the first inhalation of the newborn was 45cc, and they therefore advocated the use of 10 to 15cc by the operator, which they estimated was akin to:

> … the force to be used would, with the lips pursed to whistle, be felt on the wet finger about 31/2 to 4 inches (9 or 10cm) from the mouth, or would be about the same force one would use in blowing smoke rings.[186]

Thus it was clear that physiologists and the growth of neonatal physiology were beginning to impact the clinical care of the newborn. Physiologists, such as Henderson, with an interest in neonatal and fetal physiology were beginning to enter the clinical sphere and advocate newborn care. Clinicians, such as Flagg, and Mathieu and Holman, were also beginning to utilize and consider the most up-to-date physiological research to develop and justify their resuscitative methods and care of the newborn.

Reviewing newborn resuscitation in the 1930s

As well as stimulating individuals to promote 'scientifically-based' techniques, the growing amount of neonatal and fetal physiological research also contributed to the dawning realisation that there was a lack of consensus on the subject of newborn resuscitation in Britain and America. This led to a series of critical evaluations of the problem in both countries which were the subject of medical symposia and conferences and also published in medical journals.[187]

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184 Mathieu, A. and A. Holman (1929). "Resuscitation of the asphyxiated new-born." *JAMA* **92**(23): 1917-1918. p1917.

185 Ibid. p1918.

186 Ibid. p1918.

187 [Anon] (1931). "New york obstetrical society. Meeting of december 9, 1930." *American Journal of Obstetrics and Gynecology* **31**: 599-603,
McGrath, J. and K. Kuder (1936). "Resuscitation of the new-born." *JAMA* **106**(11): 885-890,
Wilson, R., M. Torrey, et al. (1937). "The initiation of respiration in asphyxia neonatorum." *Surgery, Gynecology and Obstetrics* **65**(5): 601-622,
Russ, J. and R. Strong (1941). "Resuscitation of the asphyxiated newborn infant." *American Journal of Diseases of Children* **61**(1): 1-12.

One of the earliest reviews of newborn resuscitation was published in 1931 by Prof Pol Coryllos, Professor of Clinical Surgery at Cornell University.[188] Coryllos had attended a 1930 New York Obstetrical Society Symposium on newborn resuscitation and remained concerned that the lack of consensus on the resuscitation of the newborn had not been resolved. He was also heavily influenced by the advances made in neonatal physiology at the time, and provided a comprehensive review of the physiological literature which reflected the changing physiological conception of the newborn.[189] He emphasized that in the asphyxiated newborn the 'lungs fill the thorax completely, so that there is no negative intraplueral pressure, and on opening the thoracic wall collapse of the lung and pneumothorax will not be produced as in grown-up persons'.[190] He described the atelectatic lungs in the healthy newborn which were gradually opened over the first few breathes, and were not fully expanded for several days.[191]

Coryllos moved onto to critique the popular treatments of the asphyxiated newborn by using the changing understanding of the newborn's physiology from the work of Barcroft and his contemporaries. He immediately dismissed the older methods of "swinging, spanking and chilling", deeming them to be 'empiric and unscientific methods, which can render some services in extreme emergency but generally do more harm than good'.[192] Having dismissed those, Coryllos was left with the three 'modern' methods to discuss: Henderson's inhalatory method; Flagg's intratracheal suction and insufflation method; and the negative pressure Drinker respirator.

Based on the physiology research of Haldane and Henderson, he stated that the most rational procedure would: 'remove or lessen any resistance to the respiration, relieve anoxemia as quickly as possible, assure a good expansion of the lungs

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188 Coryllos, P. (1931). "Atelectasis, asphyxia and resuscitation in the newborn." *American Journal of Obstetrics and Gynecology* **21**: 512-525.

189 Ibid.

190 Ibid. p513.

191 Ibid.p513.

192 Ibid. p523.

and prevent washing out of CO_2'.[193] He argued that Henderson's method would only be effective in cases of slight asphyxia, although he found it to be safe and simple.

However, for more advanced cases of asphyxia, i.e. asphyxia pallida, Coryllos was adamant that only Flagg's method of endotracheal suction and intubation was effective. He argued that any clinician could and should be familiar with it. In cases of advanced asphyxia, in which this method was especially indicated, the absence of the laryngeal reflex rendered the procedure easy and harmless.[194] Coryllos regarded the Drinker method as more suitable for long term ventilation, especially for cases of polio. He argued that it could not guarantee the patency of the airway in the newborn and was not as efficient as Flagg's at supplying carbon dioxide and oxygen directly to the lungs.

The Americans were not alone in their attempts to evaluate and standardise newborn resuscitation during the 1930s. In 1935 the British clinician, Alan Moncrieff (1901-1971), published a series of articles in the *Lancet* with similar aims.[195] Moncrieff was a well respected paediatrician, who had spent time in both France and Germany during the interwar years studying respiratory failure in the newborn. He returned in 1933 and was given posts at the Queen Charlotte's Maternity Hospital, Hospital for Sick Children, and the Postgraduate Medical School, Hammersmith Hospital, and also established a lucrative private practice.[196]

Moncrieff's series of three articles dealt with the causes, diagnosis and treatment of respiratory failure in the newborn, with reference to asphyxia neonatorum. Moncrieff was greatly concerned by the neonatal mortality rates in Britain, and commented that:

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193 Ibid. p523.

194 Ibid. p524.

195 Moncrieff, A. (1935a). "Respiratory failure including the so-called asphyxia neonatorum." *Lancet* **1**: 531-536.
Moncrieff, A. (1935b). "Respiratory failure including the so-called asphyxia neonatorum." *Lancet* **1**: 595-600.
Moncrieff, A. (1935c). "Respiratory failure including the so-called asphyxia neonatorum." *Lancet* **1**: 664-669.

196 Norman, A.P. (2004). Moncrieff, Sir Alan Aird (1901-1971), *Oxford Dictionary of National*

> … while the infantile mortality-rate has decreased amazingly during this century, the death rate during the first month of life has failed to show anything like a corresponding decrease, and among causes of death in this neonatal period the disorder known as "asphyxia neonatorum" figures too largely.[197]

He was familiar with Barcroft's research on the fetus in the later stages of pregnancy, 'with a decreasing oxygen tension and an increasing carbon dioxide tension as growth proceeds', and he lamented that little was yet known about the initiation of the first breath.[198] He concluded that:

> It is clear that central respiratory failure due to chemical factors occurs because the normal state borders so closely upon the pathological. Any slight exaggeration of oxygen deficit or carbon dioxide excess, for example, and respiratory embarrassment will ensue.[199]

Again Moncrieff raised the concern of how one would distinguish cases requiring resuscitation. His major argument was that many cases that were thought to be asphyxia neonatorum, were in fact cases of obstruction, either from mucus or from a flaccid oesophagus.[200] Although familiar with the growing physiological evidence that the newborn was distinct from the adult, he did not believe that newborns required a different method of resuscitation.

Moncrieff found positive-pressure inhalatory methods 'unsafe' and 'quite unsuitable', and although intubation may have been 'an ideal method in theory', he argued that it required a high degree of skill.[201] He viewed the Drinker apparatus as 'complicated and costly machinery'.[202] His familiarity with the research of

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Biography, Oxford University Press. http://www.oxforddnb.com/view/article/37778?docPos=2

197 Moncrieff, A. (1935a). "Respiratory failure including the so-called asphyxia neonatorum." *Lancet* **1**: 531-536. p534.

198 Ibid. p534.

199 Ibid. p535.

200 Ibid. p536.

201 Moncrieff, A. (1935c). "Respiratory failure including the so-called asphyxia neonatorum." *Lancet* **1**: 664-669. p666.

202 Ibid. p666.

Eastman and Barcroft had convinced him of the dangers of high concentrations of carbon dioxide, and so he advised the use of carbon-dioxide-oxygen mixtures.[203]

Moncrieff concluded that:

> No apparatus, however excellent, is any substitute for two resuscitation measures in acute cessation of breathing, which must be emphasized again at the risk of tedium: the air-ways must be cleared of obstruction, and artificial respiration by the Schafer method must be employed at once.[204]

Although Moncrieff was familiar with the contemporary physiological research, and invoked it to criticize some of the popular resuscitation methods, he was reluctant to embrace the newer techniques which were being advocated during the period. Moncrieff's article reflected the fears over the safety of these 'modern' techniques, which were prevalent at this time.

This physiologically informed approach was also evident in a review of newborn resuscitation undertaken by clinicians at the Methodist Episcopal Hospital, Brooklyn from 1927 to 1937, which examined 17, 860 live births.[205] The investigation was conducted by Robert Wilson, Allen Torrey and Katherine Johnson and was funded by the Lindredge Research Fund.

Wilson *et al* were clearly stimulated by the work of the physiologists, who were beginning to view the newborn as physiologically distinct from the adult or child, as their paper made a clear distinction between older methods of resuscitation, such as the swinging methods, which they argued would only work in older children and adults and not in asphyxiated newborns with unexpanded lungs, and the newer methods.[206] Like the other reviews, they dismissed the older methods due to their 'futility, exposure to cold, and risk of injury' and so evaluated only three methods in

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203 Ibid. p666.

204 Ibid. p665.

205 Wilson, R., M. Torrey, et al. (1937). "The initiation of respiration in asphyxia neonatorum." *Surgery, Gynecology and Obstetrics* **65**(5): 601-622.

206 Ibid. p604.

detail.[207] These three methods were the Drinker respirator, endotracheal intubation with positive pressure and Henderson's inhalatory method.

Although they admitted that the efficacy of the Drinker apparatus in adults and children was 'beyond question', they argued that the device was not effective in the infant who had never breathed.[208] Referring to the physiology research of Coryllos and Birnbaum, they argued that it had been shown that higher pressures are required initially to overcome lung cohesion forces in the newborn, and that the Drinker apparatus could not provide these initial higher pressures. Wilson and his colleagues concluded that 'the Drinker respirator as employed … [had] little if any place in the initiation of respiration in the newborn'.[209]

They further dismissed the inhalatory method of resuscitation recommended by Henderson, based on Eastman's 'Foetal Blood Studies', again highlighting their familiarity with the physiological research of the time. Wilson and his colleagues argued that it was only an effective method in babies who were asphyxiated but breathing, because only these infants would inhale the gas mixture. Their study was concerned with severely asphyxiated infants, who had made no effort to breathe.[210] The inhalatory method made no attempt to maintain a patent airway and was therefore useless in such cases. Their familiarity with the fetal and neonatal physiology also allowed Wilson and his colleagues to dismiss the tilting method, as it did not fit with the contemporary physiological knowledge of the asphyxiated newborn.[211]

Wilson travelled throughout the US and UK presenting this research to obstetrical, gynaecological and other interested medical societies. His research was discussed supportively in leading research journals of the time, including both the *Lancet* and *the British Journal of Obstetrics and Gynaecology*.[212] Thus illustrating

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207 Ibid. p604.

208 Ibid. p606.

209 Ibid. p608.

210 Ibid. p610.

211 Ibid. p611.

212 [Anon] (1937). "Reports of societies: Royal society of medicine (section of obstetric and

that not only their work, but also the contemporary neonatal physiology, was being disseminated throughout the networks of obstetricians in both the US and UK.

A physiologically informed approach to newborn resuscitation?

As already mentioned, this re-evaluation of newborn resuscitation was strongly linked to developments in neonatal physiology. The contemporary physiological research was being invoked by clinicians, such as Wilson and Torrey and Moncrieff, to evaluate the various resuscitative methods in use.[213] Clinicians also used neonatal and fetal physiology research to develop resuscitative methods, such as the use of positive pressure ventilation by Mathieu and Holman.[214] Further evidence for this link between advances in newborn physiology and clinical practice can be found in the use of Nicholson J Eastman's findings by clinicians. As has been discussed previously, through his series of five articles on 'Foetal Blood Studies', Eastman made huge advances in the understanding of the relationship between fetal and maternal blood; blood biochemistry of asphyxia neonatorum; and also the effect of obstetrical anaesthesia and analgesia on the fetus and newborn.[215] He strongly disagreed with Henderson's theory, and even went so far as to claim that carbon dioxide could in fact be harmful to the asphyxiated newborn.

Eastman's research was immediately viewed as significant by those evaluating the popular methods of newborn resuscitation. An editorial in the *Lancet* in February

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gynaecology.)." *BJOG: An International Journal of Obstetrics and Gynaecology* **44**(3): 594-597, [Anon] (1937). "Annotations: The treatment of asphyxia neonatorum." *Lancet* **1**: 995-996.

213

Moncrieff, A. (1935a). "Respiratory failure including the so-called asphyxia neonatorum." *Lancet* **1**: 531-536,
Wilson, R., M. Torrey, et al. (1937). "The initiation of respiration in asphyxia neonatorum." *Surgery, Gynecology and Obstetrics* **65**(5): 601-622.

214

Mathieu, A. and A. Holman (1929). "Resuscitation of the asphyxiated new-born." *JAMA* **92**(23): 1917-1918.

215

Eastman, N. (1930). "Fetal blood studies i. The oxygen relationship of umbilical cord blood and birth." *Bulletin of the Johns Hopkins Hospital* **47**(4): 221-230,
Eastman, N. (1931). "Fetal blood studies ii. The lactic acid content of umbilical cord blood under various conditions." *Bulletin of the Johns Hopkins Hospital* **48**: 261-268,
Eastman, N. (1932). "Foetal blood studies iii.The chemical nature of asphyxia neonatorum and its bearing on certain practical problems." *Bulletin of the Johns Hopkins Hospital* **50**(1): 39-50,
Eastman, N., E. Ceiling, et al. (1933). "Foetal blood studies iv. The oxygen and carbon dioxide dissociation curves of foetal blood." *Bulletin of the Johns Hopkins Hospital* **53**(5): 246-254,
Eastman, N. (1936). "Foetal blood studies v. The role of anesthesia in the production of asphyxia neonatorum." *American Journal of Obstetrics and Gynecology* **31**(4): 563-572.

1932, discussed how Eastman's research could impact on the choice of resuscitative measure.[216] The *Lancet* concluded that:

> It should be recognized though that neither is without danger, since ribs may easily be fractured by rough handling and the lung or stomach ruptured by too vigorous insufflation. Oxygen may also be given directly by mask or nasal catheter, and probably the ideal method would be a combination of the former with artificial respiration carried out by a Drinker respirator.[217]

Eastman's research findings were also influential on the work of two British obstetricians, JB Blaikley and GF Gibberd. In March 1935 Blaikley and Gibberd published an important paper describing their method of tracheal intubation using a modified laryngoscope.[218] They were essentially advocating a similar technique to Flagg for the treatment of asphyxia neonatorum. However they had developed the technique unaware of the research published by Flagg in America.[219]

Blaikley and Gibberd identified a change in medicine, specifically regarding the resuscitation of the newborn, which had moved away from practice dictated by the experiences of clinicians and instead was 'the result of the application of new knowledge of the physiology of respiration' and of the newborn.[220] They were clearly influenced by the work of Barcroft and Eastman and had adopted the new physiological conception of the neonate. Blaikley and Gibberd stated that: 'It is now generally accepted that the provision of a supply of oxygen, and at the same time prevention of too excessive elimination of carbon dioxide, are the essentials for stimulation of adequate respiratory efforts.'[221]

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216 [Anon] (1932a). "Annotation: Asphyxia neonatorum." *Lancet* **1**: 411.

217 Ibid.

218 Blaikley, L. and G. Gibberd (1935). "Asphyxia neonatorum: It's treatment by tracheal intubation." *Lancet* **1**: 736-739.

219 Ibid. p736.

220 Ibid. p736.

221 Ibid. p736.

The influence of Eastman, Barcroft, Corryllos and Birnbaum was again evident when Gibberd and Blaikley argued that the aim of resuscitation ‘is to ensure the primary unfolding of the atelectatic lung’ and that:

> As soon as the primary distension of the alveoli has been accomplished oxygenation of the blood rapidly occurs, so that the medullary centre recovers its sensitivity and the flaccid laryngeal muscles recover their tone. Thus it is seldom necessary to leave the catheter in the trachea for longer than a few minutes; but if cyanosis subsequently recurs the operation should be repeated.[222]

They showed a clear understanding of the neonatal physiology. They had also been further stimulated to conduct clinical research to determine the correct pressure to use in treatment to prevent damage to the lungs in a bid to tackle the fears surrounding the safety of the technique. Adopting the scientific research methods of physiologists they found that a four pound infant should be treated with a number three catheter with a pressure of 32cm of water, to get a 15cm of water pressure in the bronchi, whereas a seven pound infant should be treated with a number four catheter and a pressure of 31cm of water to achieve the equivalent pressure in the bronchi.[223] They further argued that the chest wall provided enough resistance to prevent damage due to any sudden expansion of the lungs.

Despite this familiarity with neonatal and fetal physiological research methods, when it came to providing clinical evidence to support their resuscitative method they reverted to common medical empiricism using case studies, providing two detailed cases of successful treatment. Blaikley and Gibberd did not present their method as the best approach in all cases of asphyxia and they made a clear distinction between mild (asphyxia livida) and severe (asphyxia pallida) forms of the illness. They argued that it was only applicable to the severe cases, i.e. asphyxia pallida, normally denoted by flaccidity of the laryngeal and pharyngeal muscles. Again this article reflects the realisation that there were different types of asphyxia, and not all should be considered seriously pathological and in need of active resuscitation.

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[222] Ibid. p738.

[223] Ibid. p738.

Blaikley and Gibberd's paper highlighted a change in medical practice towards more physiologically-informed research with the introduction of clinical research in medical science, as well as a change in treatment of the newborn based on newer physiological concepts. These trends were again reflective of wider changes in medicine in Britain during the interwar period. This change was evident in the editorial which accompanied Blaikley and Gibberd's paper which stated:

> We are inclined to lay less emphasis on the classification of a disease than on a thorough understanding of its processes, and signs and symptoms are regarded less as pieces of a puzzle, which should fit together into some recognized pattern, than as clues which may aid us to visualise the difficulties under which some physiological activity of the body is labouring.[224]

The editor praised the work of Gibberd and Blaikley, Moncrieff, and Henderson, amongst others, as each had helped to educate their readers on advances in newborn physiology and also advocated this new physiologically-influenced approach to newborn care.

Further evidence of the growing appreciation of the clinical significance of neonatal and fetal physiology can be found in another *Lancet* editorial in 1938.[225] The editorial, 'Babies who do not breathe' discussed the fears over high neonatal mortality rates, especially those associated with birth asphyxia and the new methods of resuscitation which had been introduced by Flagg and Gibberd and Blaikley.[226] It referred to the 'recent research' of Barcroft, on intra-uterine respiratory movements, as well as the depressant effects of obstetrical anaesthesia on the newborn, which both Barcroft and Eastman had identified.[227] The editor argued that physiological evidence supported the use of endotracheal intubation, which ensured the baby's airway was clear of obstruction and could provide intermittent positive pressure insufflation.[228]

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224 [Anon] (1935). "Treatment of asphyxia neonatorum." *Lancet* **1**: 751-752.

225 [Anon] (1938). "Babies who do not breathe." *Lancet* **2**: 731.

226 Ibid.

227 Ibid.

228 Ibid.

As has been mentioned, Barcroft had published some of his fetal and neonatal research in medical journals, aware of its clinical significance.[229] This view was shared by medical journals, which regularly reported on advances in neonatal and fetal physiology.[230] One of the most clinically relevant reports on Barcoft's research was published in 1939. The editorial, 'Respiration in utero' commented on the recent publications of Barcroft and Barron, which demonstrated fetal respiratory movements.[231] The editor stated:

> All these observations suggest that the aspiration of fluid is not an accidental consequence of labour but a normal consequence of foetal respiration, and a means of dilating the future air-passages. When therefore a newborn child fails to breathe [at birth], the question to be asked is not what should cause the first breath, but what has interfered with existing respiratory movements.[232]

Again this research challenged the prevalent clinical understanding of the asphyxiated newborn. Barcroft was suggesting that the lungs were not completely atelectatic at birth and that some fluid in the lungs was not pathological.

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Examples of Barcroft's publications in medical journals include:
Barcroft, J. (1933). "The conditions of foetal respiration." *Lancet* **2**: 1021-1024.
Barcroft, J. (1939). "The intra-uterine development of respiratory effort." *BMJ* **ii**: 986-987,
Barcroft, J. (1941). "Four phases of birth." *Lancet* **2**: 91-95,
Barcroft, J. (1942). "The onset of respiration at birth." *Lancet* **2**: 117-120,
Barcroft, J. (1942). "Respiratory patterns at birth." *Cambridge University Medical Society Magazine* **20**: 6-9.

230

Examples of articles in medical journals discussing advances in neonatal and fetal physiology which are deemed to be of clinical relevance include:
Barton, E. (1915). "The condition of the larynx and trachea in the stillborn infant and its bearing on artificial respiration." *BJOG: An International Journal of Obstetrics and Gynaecology* **27**(3): 138-140,
Coryllos, P. (1931). "Atelectasis, asphyxia and resuscitation in the newborn." *American Journal of Obstetrics and Gynecology* **21**: 512-525,
Moncrieff, A. (1935a). "Respiratory failure including the so-called asphyxia neonatorum." *Lancet* **1**: 531-536,
[Anon] (1939). "Leading article: Respiration in utero." *Lancet* **2**: 838.
Again this growing appreciation of the clinical significance of neonatal and fetal physiology was representative of the wider trend in medicine during the interwar years, whereby physiology was replacing pathology as the science of medicine, and the methods of experimental physiology were being adopted by medical science during the interwar years.

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[Anon] (1939). "Leading article: Respiration in utero." *Lancet* **2**: 838.

232

Ibid.

Newborn resuscitation in the 1940s

Little was published during the 1940s in Britain and America on newborn resuscitation, mainly because of the disruption to medical research imposed by the Second World War. However a few articles and textbooks give a bit of an insight into what was being done to treat the asphyxiated newborn during this time, and unsurprisingly it is very similar to what was done in the 1930s.

In 1941 two paediatricians from the University of Louisiana, School of Medicine published the results of their review of all current resuscitative methods in use for treating the asphyxia neonatorum. They hoped that their review would determine the most effective routine for resuscitating the newborn.[233] Interestingly this is one of the earliest articles written by paediatricians, and JD Russ and Robert Strong did comment that the care of the newborn, in America at least, had increasingly become the responsibility of the paediatrician rather than obstetrician. They also scathingly commented that: ‘Numerous methods have been advocated, none of which has been entirely satisfactory. Since it became accepted that the care of the newborn infant should be entrusted to the paediatrician, progress has been more satisfactory.’[234] The involvement of the paediatrician is something which becomes increasingly significant in the decades after the war and it will be discussed in more detail in later chapters.

Russ and Strong reviewed a wide array of treatments, which reflects the variation in practice which remained across America by the 1940s. The methods they considered included: contrast baths; swinging between doctor’s legs with head down; folding “accordion“ fashion; manual compression and release of the chest; mouth to mouth; intratracheal catheter with suction of trachea and upper airways; intratracheal catheter with mechanical apparatus for insufflation with CO_2/O_2 mixture under pressure; baby laryngoscope and intratracheal catheter under direct vision; hanging infant by feet and stroking throat to clear mucus; spanking, slapping, rubbing of skin and feet; cold water on skin; aspiration of nose, mouth

233 Russ, J. and R. Strong (1941). "Resuscitation of the asphyxiated newborn infant." *American Journal of Diseases of Children* **61**(1): 1-12.

234 Ibid. p1.

and throat; drugs; CO_2/O_2 mixture via face mask; mechanical apparatus such as Drinker, or Easton and Johnson resuscitator.[235]

Russ and Strong had studied 12,000 live deliveries, with 196 requiring resuscitation, and came up with a definite procedure for treating the newborn depending on the degree of asphyxia. This routine had three steps: providing warmth, cutaneous stimulation and aspiration of the upper airways. Although they argued that these three stimuli were usually sufficient to initiate respiration in the mildly asphyxiated, they further advocated the use of intubation and positive pressure or the Easton and Johnson resuscitator for more severe cases.[236]

A review of obstetrical textbooks from the 1940s also illustrates that, despite the move towards a critical evaluation of newborn resuscitation, clinicians continued to use a wide variety of techniques. By the 1940s, the textbooks included discussion of the fetal and neonatal physiological research of Barcroft, Eastman, Henderson, and their contemporaries. This is further evidence that fetal and neonatal physiology, and physiology more generally, was increasingly accepted as clinically significant. However the textbooks also continued to advocate the older techniques such as contrast baths, tongue traction, warm bath with mustard, and tilting boards alongside the newer methods such as intubation and insufflation, the inhalatory method and the Drinker respirator, despite the mounting physiological and clinical evidence to the contrary.[237]

By the eve of the 1950s some major advances had been made in fetal and neonatal physiology, and this knowledge was beginning to filter through to the clinical sphere, as has been discussed. It contributed, along with the more general

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235 Ibid.
The Easton and Johnson resuscitator was based on Eve's rocking method of resuscitation. It was basically an electrical rocking board, on to which the asphyxiated baby could be placed to be rocked.

236 Ibid. p8.

237 Cameron, S., Hewitt, J., et al (1939). *A Glasgow manual of obstetrics, 3rd edition*. Glasgow, University of Glasgow.
Sheldon, W. (1940). *Diseases of infancy and childhood, 4th edition*. London, J & A Churchill Ltd,
DeLee, J. and J. Greenhill (1943). *Principles and practice of obstetrics, 8th edition*. Philadelphia & London, WB Saunders and Co,
Sheldon, W. (1946). *Diseases of infancy and childhood, 5th edition*. London, J & A Churchill Ltd.
DeLee, J. and J. Greenhill (1947). *Principles and practice of obstetrics, 9th edition*. Philadelphia & London, WB Saunders Ltd.

fears over infant mortality, to the critical evaluation of newborn resuscitation, based on a more scientific methodology. This trend was also apparent in British and American medicine more generally. It also led to the development of some novel methods of resuscitation, and began to have a direct influence on how clinicians decided which method to employ. Importantly though, the research on the newborn and fetus led to the realisation that the newborn was physiologically distinct from the child and adult. It highlighted the need to determine a normal base line for the newborn, so that the pathological newborn could be recognised and investigated. It also emphasized that little was known about the dramatic physiological changes and adaptations which occurred at birth, and the unique medical problems these could be associated with.

Contrary to the historiography laid out by practitioner-historians, such as Alex Robertson and Alistair Philip, which have described a ‘hands-off’ and a ‘benign neglect’ attitude to newborn resuscitation during the interwar years, I have illustrated a period of growing interest amongst physiologists and clinicians in asphyxia neonatorum.[238] Knowledge of the unique physiology of the fetus and neonate was rapidly expanded due to the research of figures such as Barcroft and Eastman. Clinicians and physiologists were also beginning to apply this new knowledge to the resuscitation of the newborn, carrying out reviews of popular methods and developing more physiologically-informed techniques.

These trends continued after the war with a productive period of newborn research during the 1950s and 1960s, which began to see a more intimate association between the physiological laboratory and the clinic. So unlike the simplistic and somewhat binary histories thus far presented, there was in fact a gradual change in newborn care and resuscitation during the early and mid-twentieth century, which will be discussed in the following chapters. The widespread and rapid post-war changes documented by practitioner-historians to date actually showed much continuity with developments of the interwar period.

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238 Robertson, A. (2003a). "Reflections on errors in neonatology i: The 'hands-off' years, 1920 to 1950." *Journal of Perinatology* **23**: 48-55,
Philip, A. G. S. (2005). "The evolution of neonatology." *Pediatric Research* **58**(4): 799-815.

Chapter 3

Who owns the neonate? The obstetrician, paediatrician, and anaesthetist, and the role of each in newborn resuscitation in the mid-twentieth century

Another important theme in the history of newborn resuscitation during the twentieth century, which became very apparent after World War II, was the involvement of two new groups of clinicians, anaesthetists and paediatricians, in the care of the neonate. Their involvement had its roots in pre-war practices, extending as far back as the late nineteenth century.

As has already been discussed, the newborn was traditionally under the care of the obstetrician or midwife, up until at least two weeks after birth. Therefore any attempts at resuscitation of the asphyxiated newborn were the responsibility of the obstetrician and his or her staff. However just as physiologists had begun to take an interest in the neonate during the interwar years, so too did anaesthetists and paediatricians. The involvement of anaesthetists in newborn resuscitation has never been thoroughly analysed, although most of the practitioner-histories written to date have mentioned contributions by individual anaesthetists such as Virginia Apgar and Joseph Kreiselman.[239] Similarly the growing role of paediatricians in the care of the newborn has yet to be examined by historians, although tensions between obstetricians and paediatricians over matters of newborn care have been hinted at.[240]This section will discuss the growing involvement of these two groups

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Virginia Apgar, who will be discussed later in this chapter, was an obstetrical anaesthetist based at Columbia University College of Physicians & Surgeons who became instrumental in promotin intubation and positive pressure ventilation for newborn resuscitation during the 1950s. She also developed the Apgar score for quick assessment of neonates at birth.

Joseph Kreiselman was another American anaesthetist who developed a face-mask for delivering positive pressure ventilation during WWII, which will be described later in this chapter.

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Tensions between obstetricians and paediatricians in Britain over the care of the neonate were mentioned during the Wellcome Witness Seminar ‘Origins of neonatal intensive care in the UK’. See: Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust. p26-27.

of medical specialists in the resuscitation of the newborn in America and Britain suring the early and mid- twentieth century.

Anaesthetists and newborn resuscitation in interwar Britain and America

Anaesthetists first began to take an interest in the possibility of applying their skills to the asphyxiated newborn during the 1920s. In the search for new ways to improve anaesthesia for surgery clinicians began to move away from tracheostomy and to experiment with endotracheal intubation. The first elective use of endotracheal intubation for surgery was performed in 1878 by the Scottish surgeon William Macewen[241]. In 1885 Joseph O'Dwyer, an American paediatrician and obstetrician, 'developed a series of metal tracheal tubes he inserted orally between the vocal cords in patients who had diphtheria and needed surgery'.[242] During the late nineteenth century a German surgeon, Franz Kuhn, developed metal endotracheal tubes with a curved tube introducer.[243] This technique was further developed by Sir Ivan Whiteside Magill during WWI. Magill 'performed several endotracheal intubations and administered endotracheal anesthesia for patients suffering from severe facial injuries.'[244] As Booth has described:

> Magill fashioned his own tracheal tubes from wide-bore rubber tubing initially bought from a shop on Tottenham Court Road. He cut the end of the tube obliquely and sterilized and lubricated it….When asked what position the head should be in and with how much cervical extension Magill replied, "as if sniffing the morning air" or "position of drinking a pint of beer".[245]

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241 Szmuk, P., T. Ezri, et al. (2008). "A brief history of tracheostomy and tracheal intubation, from the bronze age to the space age." *Intensive Care Medicine* **34**: 222-228.

242 Ibid. p226.

243 Ibid. p226.

244 Ibid. p226.

245 Booth, J. (2000). "Tracheostomy and tracheal intubation in military history." *Journal of the Royal Society of Medicine* **93**: 380-383.

The Magill rubber tubes would later be further improved with the availability of new plastics during the 1950s and 1960s, which withstood repeated boiling without deterioration.[246]

The other significant development in the history of intubation was the development of a more appropriate laryngoscope. Although Joseph O'Dwyer had developed an introducer for his metal endotracheal tubes, intubation still depended on blind insertion.[247] Alfred Kirstein developed a laryngoscope with a light, which was further modified by Chevalier Jackson.[248] Jackson was an anaesthetist from Philadelphia who designed a laryngoscope which allowed for direct vision intubation in 1913.[249] This design was further modified by other anaesthetists, including Paluel Flagg, Magill, Henry Janeway and Robert MacIntosh, amongst others.[250]

The American anaesthetist Paluel Flagg was to become instrumental in the development of endotracheal intubation under direct vision for the resuscitation of the newborn infant, as well as promoting intubation more generally. Flagg had been introduced to endotracheal intubation by Chevalier Jackson, and worked under his supervision when developing his laryngoscope for direct vision intubation.[251] Flagg was prompted to consider the problem of asphyxia of the newborn by an article by the physiologist Yandell Henderson (1873-1944). Henderson, who has been discussed in the previous chapter, was a physiologist from Yale University, who advocated the use of a face mask and positive pressure ventilation for newborn resuscitation.

Flagg was inspired by Henderson's article to consider how his own research could be applied to the asphyxiated newborn, and therefore improve the treatment

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246 Ibid.

247 Cooper, R. (2004). "Laryngoscopy - its past and future." *Canadian Journal of Anesthesia* **51**(6): R1-R5.

248 Ibid.

249 Szmuk, P., T. Ezri, et al. (2008). "A brief history of tracheostomy and tracheal intubation, from the bronze age to the space age." *Intensive Care Medicine* **34**: 222-228.

250 Ibid.

251 Flagg, P. (1927). "Intratracheal inhalation." *Archives of Otolaryngology* **5**: 394-399.

available. He agreed on the need to supply a mixture of carbon dioxide and oxygen to the newborn, but felt that the method of administration could be improved by use of a laryngoscope and endotracheal tube (see figure 5 p58).[252] This was the first published description of the endotracheal intubation of an asphyxiated newborn using a laryngoscope under direct vision. Although obstetricians had been using various forms of positive pressure ventilation to treat asphyxia neonatorum sporadically for centuries, this was the first time an anaesthetist applied his specific skills to the problem.

Originally Flagg had been concerned at how the newborn's airway was treated, and recommended to an obstetric colleague that a routine toilet of the airway should be employed using direct vision. Flagg therefore adapted his laryngoscope for use in the newborn, and described how it could be used to expose the larynx easily and safely allow the suction of mucus and debris.[253] He argued that for most asphyxiated infants this alone, or in conjunction with pharyngeal insufflation, would be enough to allow them to initiate respiration on their own. However, in the more severely asphyxiated, intubation may be necessary. He stated that a good indication of whether intubation should be performed was:

> The state of the reflexes of a baby's larynx … If a baby has a relaxed, open larynx, intubation should be done. The baby whose larynx offers resistance to intubation will do very well with artificial respiration by pharyngeal insufflation.[254]

Another anaesthetist, Joseph Kreiselman, developed an alternative method of resuscitation. Kreiselman had originally developed his bag and face-mask apparatus during the Second World War, when he had worked as a US Army consultant on anaesthesia.[255] However, after the war he began to advocate its use for newborn resuscitation.[256]

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252 Flagg, P. (1928). "The treatment of asphyxia in the newborn." *JAMA* **91**: 788-791.

253 Ibid.

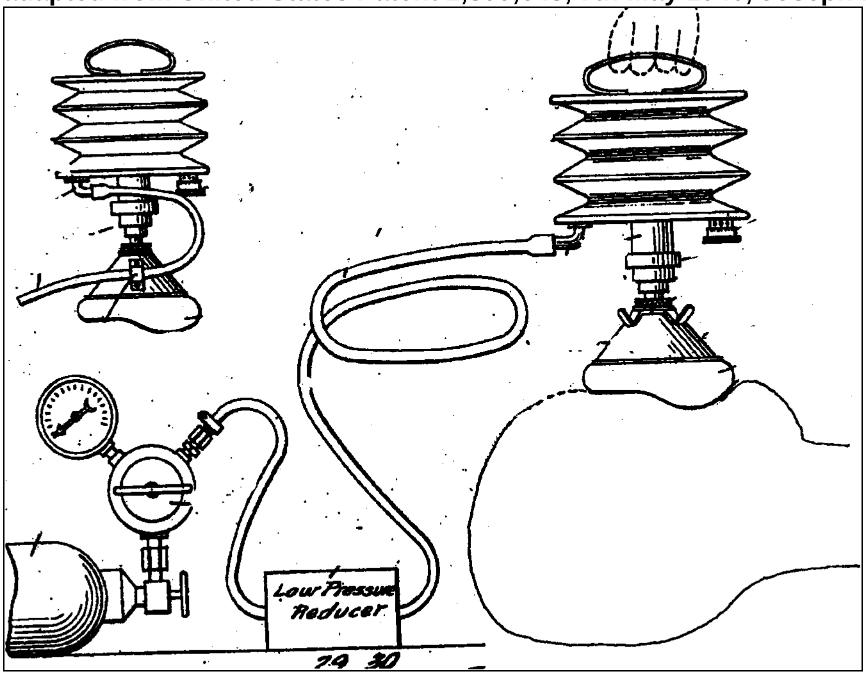
254 Ibid. p789.

255 Kreiselman, J. (1943). "A new resuscitation apparatus." *Anesthesiology* **4**(6): 608-611.

256 Kreiselman, J. (1945a). "The treatment of asphyxia." *Southern Medical Journal* **38**: 598-604, Kreiselman, J. (1945b). "The treatment of asphyxia." *Journal of the Connecticut Medical Society*

Kreiselman's apparatus was composed of an expandable accordion-like bag which was attached to a face mask via a valve (See figure 8). It was used to provide positive pressure insufflation. Although this apparatus resembled that of Yandell Henderson, Kreiselman was adamant that the only requirement for the treatment of asphyxia in the newborn was the supply of oxygen. He deemed the use of carbon dioxide not only 'superfluous' but 'harmful'.[257]

Figure 7. The Kreiselman face-mask for intermittent positive pressure resuscitation. Image adapted from United States Patent 2,399,643, 7th May 1946, Joseph Kreiselman.



Anaesthetists were not just interested in applying their ventilation techniques to newborn resuscitation, they were also concerned by the effect of obstetrical anaesthesia and analgesia on the fetus and neonate. With the hospitalization of birth and the increasing expectation of pain-free labour, anaesthetists soon became a regular presence in labour wards. By the 1930s this enthusiasm for pain-free births began to be linked to the apparent increase in newborns with depressed respiration.

9: 94-99,
Kreiselman, J. (1945c). "The treatment of asphyxia." *Anesthesiology* **6**(6): 654-655,
Kreiselman, J. (1946). "The treatment of asphyxia." *Obstetrical and Gynecological Survey* **1**(2): 203-204.

257 Kreiselman, J. (1945c). "The treatment of asphyxia." *Anesthesiology* **6**(6): 654-655.

During the 1930s growing suspicions that obstetrical anaesthesia and analgesia were having a detrimental effect on the newborn and fetus led to several studies by clinicians and physiologists. Nicholson Eastman, from Johns Hopkins Hospital, Baltimore, who had already conducted pioneering research on blood biochemistry of the fetus and newborn, published his final paper in the series ‘Foetal Blood Studies’ in 1936.[258] It had already been argued that the anaesthetic effect of nitrous oxide was due to ‘the associated anoxemia rather than to any intrinsic anaesthetic quality’.[259] Eastman stated that it was therefore justifiable to think that these blood chemical alterations in the mother extended to the child *in utero*. However there was a lack of any substantial evidence to support this view. He hoped his study would provide such evidence.

Eastman examined blood samples from 40 infants delivered under various anaesthetics and stated that:

> The results of this study would seem to justify the conclusion that nitrous oxide oxygen anesthesia, administered to the mother in concentrations sufficient for operative obstetrics, occasionally reduces the oxygen content of the umbilical blood to extremely low levels. Lack of oxygen kills tissues as quickly as many active poisons, and it is only reasonable to assume that such levels of anoxemia as we have described exert harmful and even fatal effects on the child at birth.[260]

He continued to detail how sustained experimental anoxemia could lead onto the same physiological changes as seen in clinical cases of asphyxia neonatorum, and argued that the careless use of obstetrical anaesthesia and analgesia could be responsible for the high incidence of asphyxiated newborns.[261]

From his research and the research of others, Eastman was able to draw four conclusions. Firstly, that chloroform, although harmless to the fetus, could be toxic to the mother, and should therefore not be administered as an obstetric anaesthesia. Secondly, he stated that although ether could depress the oxygen

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258 Eastman, N. (1936). "Foetal blood studies v. The role of anesthesia in the production of asphyxia neonatorum." *American Journal of Obstetrics and Gynecology* **31**(4): 563-572.

259 Ibid. p563.

260 Ibid. p569.

261 Ibid. p570.

saturation of fetal blood, it was not at a sufficient degree to cause injury through anoxemia. Thirdly, he argued that ‘ nitrous oxide oxygen mixtures, administered to mothers in proportions of 85:15 or weaker, and for periods of less than five minutes, regularly cause moderate degrees of fetal anoxemia but the normal, full-term infant is apparently not harmed’.[262] Fourthly, if nitrous oxide oxygen was given at concentrations of 90:10 or stronger over periods longer than five minutes there were ‘marked degrees of fetal anoxemia … produced in about one baby out of three and occasionally profound asphyxia neonatorum results’.[263]

Similarly in Britain Joseph Barcroft and his colleagues published a paper ‘The effect of urethane on the onset of respiration at birth’ in 1937.[264] In this paper they demonstrated that urethane anaesthesia of the ewe, by extension to the fetus, delayed the onset of respiration in the latter.[265] However, if the ewe was given a spinal anaesthetic, ‘the onset of respiration in the foetus could occur, presumably through the mechanical stimuli evoked by handling it, even before the cord had been tied’.[266]

Like Barcroft and Eastman, Franklin Snyder and Morris Rosenfeld, from Johns Hopkins Hospital, also found that the fetus was sensitive to narcosis.[267] They had conducted their research on fetal rabbits and had demonstrated that relatively low levels of analgesia in the mother could abolish fetal respiratory movements.[268]

This research, and the debates which surrounded it, contributed to the growing anxiety around the dangers of both anaesthesia and analgesia for the newborn, as well as concerns over mental retardation and its links to birth asphyxia. By the

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262 Ibid. p572.

263 Ibid. p572.

264 Barcroft, J., D. Barron, et al. (1937). "The effect of urethane on the onset of respiration at birth." *Journal of physiology* **90**: 29.

265 Ibid.

266 Franklin, K. (1953). *Joseph Barcroft 1872-1947*. Oxford, Blackwell Scientific Publishing, p248.

267 Snyder, F. and M. Rosenfeld (1937). "Direct observation of intrauterine respiratory movements of the fetus and the role of carbon dioxide and oxygen in their regulation." *American Journal of Physiology* **119**: 153-166.

268 Ibid. p166.

1940s and 1950s the depressant effect of obstetrical drugs on the newborn was widely accepted and obstetrical anaesthesia and analgesia was accordingly adjusted to minimize this risk. By the 1950s the anaesthetist had developed a voice in debates surrounding the asphyxiated neonate, not only advocating resuscitation techniques but also becoming involved in discussion about how the care of the mother had an impact on the fetus and newborn. Thus the obstetrical anaesthetist after the Second World War was not only concerned with the mother, but also the fetus and newborn in the labour ward and beyond.

Anaesthetists and newborn resuscitation after WWII

Irvine Loudon has argued that, in Britain, the success of the emergency maternity services during the War, and the creation of the NHS, meant that women began to associate 'hospital' birth with a 'safe' birth.[269] This resulted in a rapid decline in domiciliary midwifery and an increase in hospital births after the War.[270] This meant that by the 1950s the newborn was increasingly coming under the gaze of new medical specialists such as the anaesthetist, who was there to administer pain relief to the mother.

In 1949 Dr Hilda Roberts, an anaesthetist at Hammersmith, published an article in the *Journal of Obstetrics and Gynaecology of the British Empire*, which spelled out the role of the anaesthetist after WWII in newborn resuscitation, as she viewed it.[271] As an anaesthetist, Roberts was clearly influenced by the work of Flagg who, as has already been discussed, had first introduced direct vision endotracheal intubation and insufflation for newborn resuscitation in the 1920s. Roberts advocated the use of Flagg's technique of direct vision endotracheal intubation for newborn resuscitation. Aware of the scepticism surrounding the technique, she

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Loudon, I. (1992). *Death in childbirth. An international study of maternal care and maternal mortality, 1800 - 1950.* Oxford, Clarendon Press. p263.

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Ibid.
Marland, H. (2003). "Childbirth and maternity". in *Companion to medicine in the twentieth century*. J. Pickstone and R. Cooter (Ed.). London & New York, Routledge**:** p559-574.
Williams, A. (1997). *Women & childbirth in the twentieth century. A history of the National Birthday Trust Fund 1928-93.* Gloucestershire, Sutton Publishing.

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Roberts, H. (1949). "An anaesthetists contribution to the resuscitation of the newborn." *BJOG: An International Journal of Obstetrics and Gynaecology* **56**(6): 961-970.

stated that paediatricians, obstetricians and anaesthetists should all be capable of performing this ‘simple’ procedure.[272]

Overall Roberts believed that paediatricians, obstetricians, anaesthetists and nursing staff had a role to play in newborn resuscitation. This point was emphasised in her concluding remarks:

> Whatever method of resuscitation used, the mainspring of the treatment is an established routine. The nursing staff play their part by keeping the apparatus in working order and in complete readiness. The anaesthetist should be ready to intubate the infant if necessary and supervise any resuscitative measures applied; although it is much better if a paediatrician is encouraged to learn how to use a laryngoscope and take charge of the infant as soon as it is born. This leaves the anaesthetist free to look after the mother, who, after all is his first consideration, but he is there if the paediatrician needs assistance.[273]

Roberts appears to have been handing over a technique developed for anaesthesia. She claimed no authority over the resuscitation of the newborn, instead, insisting that this was the domain of the paediatrician. Roberts was clear that the main responsibility of the anaesthetist was the care of the mother not the newborn.

Further evidence of the growing involvement of anaesthetists in newborn resuscitation can also be found with the publication of an article by two Brooklyn-based anaesthetists, Bernard Cappe and Irving Pallin in 1951.[274] Cappe and Pallin were very familiar with the current physiological understanding of the newborn, and began by discussing the various theories concerning the initiation of respiration at birth, stressing that it was a contentious issue. They also preferred Flagg’s three tier classification system for asphyxiated newborns, and were strongly influenced by his work.

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272 Ibid. p964.

273 Ibid. p968-969.

274 Cappe, B. and I. Pallin (1951). "Practical aspects of resuscitation of the newborn." *New York Journal of Medicine* **51**: 1797-1800.

Perhaps unsurprisingly the two anaesthetists stressed the need for a 'fully trained Board-eligible anesthesiologist' to be available for every obstetric unit.[275] Since 1948 the Jewish Hospital in Brooklyn where they both worked had employed an anaesthetist for obstetrics, which was subsequently increased to a team of two. This meant that an anaesthetist was always available for a birth, so that anaesthesia could be administered by a specialist, who was also specially trained in resuscitation methods.[276] It would seem that they were in some ways defending their presence in the delivery room by carving out a niche and that they viewed resuscitation as a specialist skill reserved for anaesthetists. This view was in contrast to that of Hilda Roberts, and illustrates the divided opinions amongst anaesthetists, regarding their role in newborn resuscitation.

Cappe and Pallin claimed to have lowered the hospital's neonatal mortality rates to half the national rate, with the use of this regime. They did, however, admit that it would not be viable for smaller institutions to have a full-time anaesthetist.[277] This issue was also recognised by GC Steel, a London-based anaesthetist. Steel had collaborated with the private engineering firm Messrs Sparklets, London, to develop a portable infant resuscitator for use by the GP or district midwife.[278] Steel had designed a portable oxygen cylinder with rubber tubing leading to a rubber reservoir bag and face piece, which could be easily carried by a GP or midwife to deliveries. Aware of the fears about using positive pressure, Steel assured readers that the pressure was reduced at three points in the device: the valve nozzle, the rubber bag, and the connector, and that this combination limited the 'flow of oxygen to approximately one litre per minute'.[279] Clearly Steel did not feel that the GP or midwife should attempt to intubate asphyxiated infants. This apparatus could be widely disseminated as it was commercially available.

Further evidence that anaesthetists were keen to share their skill in intubation for newborn resuscitation with other medical specialists can be found in the 1957

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275 Ibid. p1797.

276 Ibid. p1788-1789.

277 Ibid. p1798.

278 Steel, G. (1954). "New inventions: A portable infant resuscitator." *Anaesthesia* **9**(4): 309.

279 Ibid.

article by E Seward, Oxford.[280] Seward was an anaesthetist from the Nuffield Department of Anaesthetics who had designed a laryngoscope for use when an anaesthetist was not available at the birth.[281] He believed that his laryngoscope made intubation and pharyngeal toilet a lot easier for the less experienced, and had teamed up with Longworth Scientific Instrument Co. Ltd. to make it commercially available.[282]

Another significant figure from the field of anaesthesia during this period was Professor Virginia Apgar, a colleague of Joseph Kreiselman, from the Department of Anaesthesiology at Columbia University. Apgar had become increasingly interested in obstetrical anaesthesia after the Second World War, especially the effects of maternal anaesthesia on the newborn. She was also concerned by the high neonatal mortality rates in the USA, which focused her attention on the high death rate due to asphyxia. Apgar was aware of the lack of agreement over what constituted a ‘normal’ state in the newborn, as well as which infants required resuscitation and what resuscitative method should be employed.[283] Convinced that this lack of consensus was in some part the result of a lack of standardisation in the initial assessment of the newborn, Apgar set about developing a scoring system, which would rate the baby on five factors: their heart rate; respiration; muscle tone; reflex response to stimulation; and the colour of their skin.[284] She believed that the scoring system could be used to determine which infants required resuscitation and could also provide ‘a basis for discussion and comparison of the results of obstetric practices, types of maternal pain relief, and the effects of resuscitation’.[285]

280 Seward, E. (1957). "New inventions. Laryngoscope for resuscitation of the newborn." *Lancet* **2**: 1041.

281 Ibid.

282 Ibid.

283 Baskett, T. (2000). "The resuscitation greats: Virginia apgar and the newborn apgar score." *Resuscitation* **47**: 215-217.

284 Apgar, V. (1953). "Proposal for a new method of evaluation of the newborn infant." *Current Researches in Anesthesia and Analgesia* **32**: 260.

285 Ibid.

The Apgar score, as it became known, was quickly taken up by clinicians in both the US and UK, and did have a major impact on the care of the neonate, by providing one of the first steps along the path of standardising care, as well as providing a tool for comparative studies and assessment of resuscitative techniques.[286]

Apgar was also an early advocate of endotracheal intubation and positive pressure ventilation for the resuscitation of the newborn. By the late 1950s she was reportedly routinely intubating babies at the Presbyterian Hospital, New York.[287] She had a great influence on some British clinicians, who held travelling fellowships during the 1950s, and returned to England advocating Apgar's routine for newborn resuscitation.[288] This influence will be discussed in later chapters.

What is interesting to note is that most anaesthetists did not attempt to claim authority over the newborn, although there were some exceptions. On the whole they shared their own skills and knowledge with obstetricians and paediatricians. It was clear that they felt that all three specialists should be prepared to treat the asphyxiated newborn. Interestingly there was never any resistance to the involvement of the anaesthetist in newborn resuscitation from obstetricians, although not all supported the use of endotracheal intubation and positive pressure ventilation. It was clear that many obstetricians felt that intubation was a specialist skill best performed by an anaesthetist, and therefore they did not object to their involvement in newborn resuscitation. This lack of objection could also be explained by the fact that obstetricians viewed the role of the anaesthetist in newborn care as limited merely to resuscitation. However, the involvement of paediatricians was not as welcome, possibly because they were viewed as more of a threat to obstetrics as a whole.

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286 Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust.
MacFarquhar Desmond, M. (1998). *Newborn Medicine and Society. European background and American practice (1750-1975).* Austin, Eakin Press. p137.

287 Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust p19.

288 Ibid.

A role for paediatricians in newborn care?

Just as anaesthetists were entering the debates over the resuscitation of the newborn, paediatricians were also increasingly being invited into the labour suites after the war, and they were gaining authority over the newborn. The post-war establishment of the NHS in Britain contributed to both the hospitalisation of birth and the growth of paediatrics in Britain. As new posts were created in the NHS hospitals, these young paediatricians attempted to stretch the boundaries of their specialty and began to look towards the newborn and to enter the labour suite in greater numbers by the 1950s. However, unlike anaesthetists, the role of paediatricians in the care of the neonate was sometimes contentious. By analysing the discussions and publications around the problem of newborn resuscitation during the 1950s, these tensions can be illuminated and examined.

In 1951 two paediatricians from the University of Toronto, John Fletcher and Joslyn Rogers, published an article on their method of newborn resuscitation in *JAMA*.[289] They called for good antenatal care to monitor for fetal distress, good obstetric technique and also the administration of minimal sedation and anaesthesia to the mother.[290] They were clear that the role of the paediatrician was to manage the asphyxiated newborn immediately.[291]

Fletcher and Rogers developed a novel adaptation of endotracheal intubation by using concentric endotracheal tubes.[292] This meant the inner tube could be repeatedly removed after suction, cleared and then replaced, thus preventing any trauma due to repeated intubation. When the operator was satisfied that the airways were clear of obstruction the inner tube could be removed and oxygen administered via a flowmeter at 6 litres per minute. However, Fletcher and Rogers argued that in the majority of cases the clearing of the airways would suffice to initiate respiration in the asphyxiated newborn.[293] They claimed to have witnessed

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289 Fletcher, J. and J. Rogers (1951). "Resuscitation of the newborn." *JAMA* **145**(8): 533-538.

290 Ibid. p534.

291 Ibid. p535-536.

292 Ibid. p536.

293 Ibid. p536

a decline in stillbirth and neonatal mortality rates over three years, and that 'resuscitation efforts would appear to have played a considerable part in this improvement'.[294]

Recognizing the trend for the increasing involvement of the paediatrician in the care of the newborn and the possible tensions surrounding it, the British Congress on Obstetrics and Gynaecology held a special symposium in 1952 on 'The place of the paediatrician in a maternity unit'.[295] Various different speakers were asked to give short papers on the topic to initiate a general discussion and a lively debate ensued. The proceedings of the symposium reflected the varied opinions of clinicians in Britain at the time regarding the role of the paediatrician in newborn care.

Wilfred Gaisford, Professor of Child Health at the University of Manchester, gave the introductory paper. Gaisford argued that there was a variety of views which could be taken regarding the role of the paediatrician in the care of the newborn. An extreme view would see the infant as "paediatric" once the mother had been discharged from obstetric care after two weeks.[296] This would mean that there was no place for the paediatrician in the maternity ward, unless the obstetrician became concerned about the baby's health during this initial period. However, Gaisford argued that the paediatrician would be at a disadvantage, lacking the experience of treating the 'normal' newborn, he would be unable to appreciate the extent to which the sick newborn differed from normal babies and also the variation which would still be regarded as physiological.[297]

At the other extreme there was the view that 'birth is only an incident in a baby's life and that much more important happenings have been occurring during the preceding nine months which are of the greatest paediatric interest and

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294 Ibid. p537.

295 Gaisford, W. (1952). "British congress of obstetrics and gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 663-666.

296 Ibid. p663.

297 Ibid. p663.

concern'.[298] In this view the paediatrician must have access to the prenatal care so he is 'able to give the best possible advice about the care of the infant in the neonatal period'.[299]

However between the two extremes more moderate views could be taken. The infant could become the responsibility of the paediatrician once it has left the labour suite, which would mean that the immediate resuscitation manoeuvres were still the responsibility of the obstetrician.[300] Or the paediatrician could attend the birth when required, such as during caesarean sections or when a difficult delivery is anticipated.[301] The paediatrician would then be responsible for the initial care and possible resuscitation of the baby.

Gaisford believed that the last view was the most appropriate. He argued that both paediatricians and obstetricians had contributed to the decline in infant mortality over the previous 20 years, and that: 'Further research should not, therefore, be limited to obstetricians, but should be conducted by a team of workers of which paediatricians should certainly be members.'[302] He contended that by inviting the paediatrician into the delivery room, the obstetrician did not have to divide his attention between the mother and the infant, and therefore both would receive better care by having their own clinician. He further reasoned that the nursery and its staff and administration should fall within the domain of the paediatrician, who would also be responsible for instructing the nursing staff on the care of newborns.[303]

However Gaisford did not want to remove the obstetrician completely from the care of the newborn infant. He still maintained that 'research in the problems of the newborn' was the joint responsibility of both the obstetrician and paediatrician, and that the maternity unit should remain under the direction of the obstetrician, who

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298 Ibid. p663.

299 Ibid. p663.

300 Ibid. p663.

301 Ibid. p663.

302 Ibid. p663.

303 Ibid. p664.

would then delegate all aspects of newborn care to the paediatrician.[304] He concluded that:

> The atmosphere necessary for the ideal unit can obviously only be provided if obstetrician and paediatrician are alike alive to the needs of their respective charges and are also mutually sympathetic one to the other; they should be in fact as much a single unit as are a mother and her infant.[305]

Francis Stabler, an obstetrician at the Princess Mary Maternity Hospital, Newcastle, was shocked that the role of the paediatrician in the maternity unit was being questioned at all. He commented that similar discussion had been 'disposed of many years ago' at his own hospital and that paediatricians had been given free rein throughout the wards, the labour rooms, theatres and nurseries.[306] He felt that the discussion had moved on beyond issues of delegation, towards issues surrounding co-operation.

Stabler had been shocked when he had recently interviewed three candidates for an obstetrics post and had found the old problem of delegation still apparent. He had asked the candidates about their knowledge of paediatrics. One reportedly replied that his knowledge was limited because he had a resident paediatrician; a second replied that he 'thought that paediatricians should take over one hour after the birth'; whilst the third commented that he would 'hand over sick and premature babies to the paediatricians'.[307] These interviewees had prompted Stabler to make further enquiries, through which he discovered that many obstetricians still held archaic views of the role of the paediatrician, and that many maternity units were in the same state that his own unit had been 20 years before.[308]

Stabler criticized these older views of the role, if any, of the paediatrician in a maternity unit. He argued that if paediatricians were only restricted to the care of

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304 Ibid. p664.

305 Ibid. p664.

306 Ibid. p666.

307 Stabler, F. (1952). "British congress of obstetrics and gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 666-670. p666.

308 Ibid. p667.

the premature or abnormal infant, or if they were simply debarred from the first 12 hours of the newborn's life, then they were debarred from full knowledge of the newborn and that they would be incapable of giving the best care available.[309] He maintained that:

> Surely if we want good work from our paediatrician, if he is to become skilled at his job, he must be there to observe and help with the baby from the moment of birth. Moreover he should be at our side for all babies, sick or well, premature or mature. To send for him only for such babies as are damaged, asphyxiated, infected, or premature in birth would be like restricting an obstetrician to abnormal cases only. Without a sound experience of the physiological process his management of the pathological would suffer.[310]

Stabler further stated that paediatricians should be involved in prenatal care so that they can learn to assess the effect of normal and abnormal labour and delivery on the baby, stating that 'the training of any paediatrician is incomplete without a full knowledge of all that goes on, physiological and pathological, from conception until the baby becomes his more direct concern.'[311]

Stabler felt the reverse was needed, and argued that just as a paediatric registrar should leave the hospital a good obstetrician, so too should an obstetric registrar leave a good paediatrician. He advocated, like Gaisford, that the obstetrician and paediatrician should function as a team with joint responsibility for the care of the newborn. Acknowledging the possible tensions which could arise, he suggested that these could be avoided if there are no rules or restrictions put in place about the province of either specialty. He stated that with 'frequent clinical and social contact' any barriers or hostility would be broken down and that 'the margin of disagreement' would soon be found to be so small that it would be 'negligible'.[312]

Stabler concluded by offering his own hospital, the Princess Royal, as an example of how both specialties could work harmoniously. The unit had ninety beds, three senior obstetricians, a first assistant, two registrars, and two house surgeons.

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309 Ibid. p667.

310 Ibid. p667.

311 Ibid. p668.

312 Ibid. p668.

They also had one senior paediatrician, with an assistant and one registrar, along with one sister and six nurses. He explained that the senior paediatrician attended management and policy meetings and was not concerned with the day-to-day care of babies. The assistant paediatrician had two rounds per week and was available for difficult deliveries, whilst the registrar was resident and was always on duty.

It is noteworthy that both these papers discuss the idea of a ‘team’ of clinicians who have responsibility for the care of the newborn. This team involves both obstetricians and paediatricians, and also anaesthetists, when present. It would appear that just as some clinicians fought over the control of the neonate, others were calling for a group effort, where the care of the neonate could be shared.

A heated discussion followed the two introductory papers, as the audience included both obstetricians and paediatricians. Beryl Corner, from Bristol, who was one of the first British paediatricians to develop a special interest in the premature infant, was the first to comment on the papers.[313] Reflecting on the history of newborn care she argued that the clinician-accoucher was traditionally responsible. However over time this role branched into obstetrics and paediatrics, therefore it was only right that the paediatrician should return to the care of the newborn.[314] She stated that as the role of the paediatrician expanded so too did his responsibilities. Firstly paediatricians must now become investigators, as they were still ‘only on the fringe of knowledge of the normal functioning of the baby’s body whether *in utero* or during infancy’.[315] They must also be able to diagnose clinical abnormalities early on, because in the newborn ‘the margin between life and death … is so narrow that the time factor is paramount’.[316]

In Bristol the first premature unit opened in 1946, and by 1950 the special care was being provided by paediatricians. Corner argued that this had allowed for

313 Corner, B. (1952). "British congress of obstetrics and gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 670-673.
Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust. p4.

314 Ibid. p670.

315 Ibid. p670.

316 Ibid. p671.

greater collaboration between paediatricians and obstetricians, which was necessary to tackle the significant problems of the neonate, namely congenital abnormalities and asphyxia neonatorum.[317]

An obstetrician, Dr E Cope of Birmingham, also agreed that the paediatrician had a place in the maternity ward. He reflected that most obstetricians had 'accepted', somewhat reluctantly, that paediatricians had not only entered the maternity hospital but that they had come to stay, and that what was therefore important was deciding how best to use their services.[318] Cope expressed the fear that unless this was discussed then paediatricians would encroach further on obstetrics, until the obstetrician was reduced to the role of merely separating the patient from its mother.

Cope described how he had witnessed the 'bloodless revolution' occur, and had seen 'various stages of the battle in various centres from various view points'.[319] Clearly he felt that this had not been an easy transition. Having worked under various systems, with varying degrees of involvement of paediatricians, Cope felt able to discuss the advantages and disadvantages of each system. The first system basically set the paediatrician as a consultant for difficult cases, with the obstetrician maintaining the care of the baby. He argued this provided 'continuity of treatment' and meant that the resident obstetricians received a thorough training in newborn care.[320] However, he did admit that this system lacked the administrative machinery for the follow-up care of the babies.

A second system allowed the Professor of Paediatrics to take over the care of babies, with a resident paediatric registrar appointed. Cope felt that this system 'divorced' the obstetric staff from the babies, which he feared would lead to an overall reduction in the efficiency of the maternity service as obstetricians

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317 Ibid. p672.

318 Cope, E. (1952). "British congress of obstetrics and gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 673-676.

319 Ibid. p673.

320 Ibid. p673.

effectively lost interest in the newborn.[321] He further argued that the paediatric resident had little experience of newborn care, which created a lack of confidence in the minds of the obstetricians.[322] Cope stated that paediatric residents in maternity units should have held an obstetric appointment before being employed.

Interestingly Cope did not think that the paediatric registrar should be responsible for newborn resuscitation. In fact he felt his involvement may become ‘another obstacle between the womb and the warmed cot’.[323] Instead he believed that the obstetrician should maintain the responsibility for resuscitation. Cope feared that this system failed to provide a continuity of treatment and which he worried could translate into a lack of confidence in the minds of the patients.

A third system allowed the obstetrician to remain in charge of the newborn for the early neonatal period, which was the first week of life, after which point the paediatrician stepped in. Cope believed that this system provided the ‘optimum service to mother and baby, allowed for excellent training for obstetric residents, and made available all the material that was required for clinical research’.[324] Although it did still have the associated problems of divided responsibility and lack of continuity, this was the system that Cope favoured.

Cope also found the final system, with the baby becoming ‘paediatric’ after warding, favourable. He explained that: ‘The obstetric residents acted within the department as their house clinicians and there was free discussion between the two groups of specialists on all clinical and administrative points.’[325] This system also provided adequate training to obstetricians, and meant that they remained informed of the baby’s progress. However it again raised problems of divided responsibility. Nevertheless, Cope viewed the care of premature babies differently. He argued that it was unimportant which specialist cared for them, and what was

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321 Ibid. p674.

322 Ibid. p673.

323 Ibid. p674.

324 Ibid. p675.

325 Ibid. p675.

important was that they were an ‘enthusiast’.[326] He argued that the only way prematurity would be ‘eradicated’ would be through collaborative research, not only between obstetricians and paediatricians, but also with physiologists, pathologists and politicians.[327]

An obstetrician, Ambery Smith, from Leeds, who although happy with the involvement of the paediatrician in newborn care, feared the encroachment of the paediatrician into the prenatal period and argued that: ‘The treatment of the mother and baby while *in utero* will remain and should remain the duty and responsibility of the obstetrician.’[328] Smith further asserted that Stabler’s statement, that the place of the paediatrician in the maternity ward was no longer the problem, was incorrect, and argued that in Leeds alone three different systems were in operation in the maternity units, and that there was still no general agreement on the issue in Britain or the USA.[329]

At the Leeds Maternity Hospital the paediatrician had complete control of all babies at birth, and this system had been adopted five years previously, and had worked ‘well and smoothly’.[330] However, like Cope, Smith also felt that this system meant that the obstetrician was divorced from the baby and therefore began to lose interest in its progress. Believing that obstetric care was an important factor in the baby’s progress, Smith worried that without the continued involvement of obstetricians, clinical research and improved obstetric care could be hindered.[331]

Smith was not only concerned about the reduced role of the obstetrician for research, but also the knock-on effect this would have on the training of general

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326 Ibid. p675.

327 Ibid. p675.

328 Smith, A. A. (1952). "British congress of obstetrics and gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 676-677.p676.

329 Ibid. p676.

330 Ibid. p676.

331 Ibid. p677.

practitioners.[332] He explained that many clinicians hoping to continue to general practice spent time as an obstetrical registrar. However, if the obstetrician is divorced from the care of the newborn, these clinicians failed to gain experience of the resuscitation of the newborn and the general care of healthy newborns. Smith feared this would translate into a poor domiciliary maternity service. He therefore argued that 'some place must be found for house-surgeons and registrars and consultant obstetricians to share the responsibility for the care of newborn babies'.[333]

The obstetrician Professor WIC Morris of Manchester also raised the issue that many maternity units were not in hospitals, and would not be able to provide a comprehensive paediatric service.[334] Therefore the 'day-to-day care of the babies must continue to be shouldered by the obstetricians' and it is 'vitally necessary … to train obstetrical house-surgeons and registrars in neonatal paediatrics'.[335]

Morris also described the friction which existed in teaching hospitals, where obstetricians and paediatricians worked together to care for the newborn. The major source of friction was when the paediatrician merely 'visited' the maternity unit and junior assistants were left to care for the newborn. Morris described how 'the consultant obstetrician attending much more frequently finds this a source of irritation.'[336] Morris described how mutual criticism was most obvious when it came to newborn resuscitation. He explained that in these circumstances a junior paediatrician was left to resuscitate the newborn, and that more often than not this duty was taken over by the anaesthetist, which Morris argued, with irritation, was 'yet another subdivision of control'.[337]

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332 Ibid. p677.

333 Ibid. p677.

334 Morris, W. I. C. (1952). "British congress of obstetrics and gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 677-678. p677.

335 Ibid. p678.

336 Ibid. p678.

337 Ibid. p678.

However, not all participants welcomed the paediatrician into the maternity unit. Professor Lennon of Bristol was concerned by the ‘invasion’ of obstetrics by the paediatrician.[338] He warned other obstetricians about ‘further loss of territory’, arguing that paediatricians could continue to ‘take liberties’ if left ‘unchecked’.[339] He explained that he refused to let a paediatrician resuscitate his babies, feeling that most of them had never held an obstetric house job, and therefore lacked the skill and experience. He further commented that, unlike obstetrical consultants, paediatric consultants were never found in the labour room at night, suggesting that they somehow had not earned the right to treat the newborn. He exclaimed that: ‘As obstetricians we have a duty to protect our specialty. We must be interested in and know about babies. For administrative matters the obstetrician must be in charge in the maternity block.’[340]

In defence of his paper Professor Gaisford stressed that he was fully aware of the friction that could occur between both professions, and that he had been particularly describing the arrangements in teaching hospitals, which he agreed were not always transferable to smaller units lacking regular paediatric care.[341] Gaisford further argued that:

> Once it was realised that obstetricians and paediatricians both had the same aim in mind – the well-being of the baby – then in the achievement of this aim there should be no grounds for disagreement in principles, although practices might vary according to local circumstances.[342]

The Symposium provides an insight into both the paediatrician’s and the obstetrician’s view of who held responsibility for the care of the newborn. As has been discussed, the views not only varied between but also within each specialty. Some paediatricians called for a stretching of their boundaries, just as some

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338 Lennon, N. K. (1952). "British congress of obstetrics and gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 679-680. p679.

339 Ibid. p679.

340 Ibid. p679-680.

341 Gaisford, W. (1952). "British congress of obstetrics and gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 680.

342 Ibid.

obstetricians feared the encroachment of their specialty. Others were happy that there should be a clear division whereby the newborn was immediately ‘handed over’ to the paediatrician, while the obstetrician remained concerned with the care of the mother, whereas others called for a ‘team’ approach towards newborn care involving both obstetricians and paediatricians, and when necessary anaesthetists. There were of course shades of grey between these views.

Evidence that the care of the newborn was also of growing concern to paediatricians in America can be found in a special round table discussion that was held at the Annual Meeting of the American Academy of Pediatrics in 1954, on ‘Special problems of the newborn’.[343] A variety of issues were discussed including the dangers of supplemental oxygen therapy, the care of the premature infant, Rhesus incompatibility, maternal diabetes, respiratory distress and also asphyxia at birth.

It is difficult to determine the wider landscape of newborn resuscitation during the 1950s in Britain and America, and gauge exactly what different hospitals did, although the British Congress on Obstetrics and Gynaecology’s 1952 symposium provides an insight into the set-up in Britain. In 1954 clinicians from the Winnipeg Maternity Hospital in Canada conducted a survey of 158 hospitals concerning their method of resuscitating the newborn.[344] Their survey included questions not only on the methods employed, but also on when resuscitation was started and why, and also who was responsible for it. The results reveal a glimpse of the state of newborn resuscitation in Canada during the mid-1950s as one of great variation, which was similar to the situation in Britain (see appendix 1).

The Winnepeg group argued that there was ‘a growing appreciation of the difficulties and need for infant resuscitation’, with 60.6 per cent of the hospitals having established a set scheme for resuscitation.[345] However, there was no consensus on when to commence resuscitation, and who should be responsible. Hospitals reported that obstetricians, paediatricians, anaesthetists and nurses of

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343 Smith, C. and C. Cook (1955). "American academy of pediatrics, inc. Proceedings and reports: Special problems of the newborn." *Pediatrics* **15**(3): 348-352.

344 Schmidt, O., M. McLandress, et al. (1956). "An evaluation of infant resuscitation." *Canadian Medical Journal* **75**: 503-506.

345 Ibid. p506.

all levels could be responsible for resuscitation.[346] Hospitals also varied in both the technique of resuscitations and the apparatus employed.

In June 1955 the American Medical Association (AMA) held a special session at their 104th annual meeting on resuscitation of the newborn. The papers presented at the session were then published in *JAMA* later that year.[347] The fact that the subject was given a special session at AMA's annual meeting, and was subsequently published in *JAMA*, reflects just how important the issue was considered in the mid-1950s, and also the different clinicians who were concerned with it. The first paper was presented by three anaesthetists from Hartford Hospital, Connecticut, Drs Ralph Tovell, William Bannister and David Little.[348] Tovell and his colleagues discussed the role of carbon dioxide and oxygen in newborn resuscitation and also the action of analeptic drugs.

Dr Richard Day, a paediatrician from Brooklyn and a colleague of Virginia Apgar, then presented his paper on the 'Expansion of the lungs of newborn infants'.[349] Day had an interest in the physiology of newborn respiration and had been researching lung expansion throughout the early 1950s. He was concerned with the pressures needed to expand the asphyxiated newborn's lungs.[350] These three papers again reflect the fact that during the early and mid 1950s no one medical specialist had sole responsibility for the care or, more specifically, the resuscitation of the newborn.

The notion of the 'resuscitation team', or more generally a team effort in newborn care, was again raised at the 29th Congress of Anaesthetists in Los Angeles in 1954. Roy Goddard discussed the role of the 'infant resuscitation team', which he

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346 Ibid. p504.

347 Day, R. (1955). "Expansion of the lungs of newborn infants." *JAMA* **159**(14): 1340-1341,
Holinger, P. (1955). "Role of the laryngologist in resuscitation of the newborn infant." *JAMA* **159**(14): 1338-1340,
Potter, E. (1955). "State of the lungs at birth." *JAMA* **159**(14): 1341,
Tovell, R. and D. Little (1955). "Resuscitation of the newborn infant." *JAMA* **159**(14): 1337-1338.

348 Tovell, R. and D. Little (1955). "Resuscitation of the newborn infant." *JAMA* **159**(14): 1337-1338.

349 Day, R. (1955). "Expansion of the lungs of newborn infants." *JAMA* **159**(14): 1340-1341. Day's research on lung expansion in the newborn will be discussed in more detail in chapter 4.

350 Ibid. p1340.

argued consisted of the obstetrician, paediatrician and anaesthetist. Goddard stated that:

> No longer is the obstetrician alone concerned with the fate of the baby at birth; the anaesthesiologist has come to join him in the past century in the safe deliverance of the baby. We as paediatricians are called upon more and more to “take over the infant who has not done well”, and to be present at an expected difficult delivery to assist in resuscitation, should it be necessary … Thus, the anaesthesiologist, the obstetrician and the paediatrician have joined together in an attempt to prevent needless neonatal deaths.[351]

As has been described, the 1950s witnessed a variety of approaches to the care of the asphyxiated newborn. Not only were there a number of techniques employed, which will be discussed in the following chapter, but there was also no consensus on just who ‘owned’ the asphyxiated newborn. The anaesthetist had entered the debates as he attempted to apply his skills in ventilation to the resuscitation of the newborn. Some anaesthetists wanted to maintain ownership of their skills and argued that the anaesthetist should have the responsibility of treating the asphyxiated neonate, whereas others were happy to pass the skill onto their paediatric and obstetric colleagues, although they insisted that the anaesthetist would always be there to help and advise. The latter advocated the popular ‘team’ approach to newborn resuscitation which was employed in many of the larger teaching hospitals and larger maternity units in both the US and UK. However, as not all babies were born in larger maternity units, many clinicians argued that simpler and more accessible resuscitation techniques should be available for general practitioners and midwives to use. This resulted in many anaesthetists developing simpler portable versions of their resuscitation equipment.

It appeared that there was little resistance from obstetricians regarding the involvement of anaesthetists in newborn resuscitation, except for those who had concerns about some of the techniques that they advocated, which will be discussed in the next chapter. However, the growing involvement of paediatricians was not as welcomed. Many obstetricians felt threatened by the presence of paediatricians in the labour suite, and feared further encroachment of paediatricians into their clinical domain. Tensions developed between both

351 Goddard, R. (1955). "The role of an infant resuscitation team in investigative studies of respiratory onset at birth." *Current Researches in Anaesthesia and Analgesia* **34**(1): 1-25-. p1.

specialties, although the exact nature of these tensions varied greatly between institutions, as has been described above. However by the end of the 1950s the presence of the paediatrician in the maternity unit, and his role in newborn resuscitation, had become accepted by most. So by the 1960s it was mainly paediatricians, rather than obstetricians, who were most vocal in debates surrounding newborn resuscitation and care. This was in part linked to the emergence of the new sub-specialty of neonatology, which will also be discussed in more detail in the following chapters.

Chapter 4

Oxygenating the newborn

The Second World War had a significant impact on medicine in Britain, which has been documented in detail by several authors.[352] Firstly it diverted medical research towards the treatment and care of the young men who were fighting in Europe. This meant that the asphyxiated newborn was no longer of prime importance to clinicians and physiologists alike, and that little progress was made on the pre-war care of newborns until the 1950s.

However, the war also benefited medicine more generally. Many advances were made during the war in medical technologies and pharmaceuticals. As Bourke has discussed, in her 2003 essay 'Wartime', '[t]he Second World War saw the large scale use of tetanus vaccines, sulfonamides, penicillin, and blood transfusions.'[353] Significantly for respiratory support, technological advances were made through aviation research for the Royal Air Force (RAF). Many clinicians involved in this war-time research were greatly influenced by war-time advances and were able to apply their skills to the care of the newborn after the war. These themes will become apparent in the following chapters with the discussion of more specific examples.

As has already been mentioned, by the end of World War II, carbon dioxide had been mostly dismissed as having no role in newborn resuscitation. The interwar physiology research by Eastman and Barcroft had established that the asphyxiated newborn already suffered an excess of carbon dioxide and that its real need was oxygen. Despite the general consensus that the asphyxiated newborn needed oxygen, clinicians and physiologists alike failed to agree on just

352 Bourke, J. (2003). "Wartime". in *Companion to medicine in the twentieth century*. R. Cooter and J. Pickstone (Ed.). London & New York, Routledge: 589-600.
Cooter, R. (1992). "The politics of spatial innovation: Fracture clinics in inter-war Britain". In *Medical innovations in historical perspective*. J. Pickstone (Ed.) London, Macmillan.
Cooter, R. (1993). *Surgery and society in peace and war*. London, Macmillan.
Cooter, R., M. Harrison, et al., Eds. (1998). *War, medicine and modernity*. Stroud, Sutton.
Cooter, R., M. Harrison, et al., Eds. (1999). *Medicine and modern warfare*. Amsterdam & Atlanta, Rodopi.

353 Bourke, J. (2003). "Wartime". in *Companion to medicine in the twentieth century*. R. Cooter and J. Pickstone (Ed.). London & New York, Routledge: 589-600. p590.

how to oxygenate the newborn. The post-war years witnessed a variety of methods of treating the asphyxiated newborn, some based on lessons learned in adults from the war, others based on physiological research from the 1930s and 1940s, and others again based on clinical experience. These resuscitative methods had varying degrees of dissemination, and drew on different physiological knowledge of the asphyxiated newborn. It will be useful to illustrate just how divergent these techniques were by providing some short descriptions of how they were used and their relative popularity. This will involve looking back to research published during the interwar years, as there was a degree of continuity of treatment after the war. It will highlight the lack of consensus on how best to treat the asphyxiated newborn, as well as the different actors who attempted to improve the care available. The three techniques I will describe in this section are: Eve's rocking method; electrophrenic stimulation; and the Bloxsom Air Lock.

The war undoubtedly had an effect on resuscitation generally, and just like during the interwar years, many of the advances made in adults filtered through to the care of the neonate. With the mobilization of the medical services during the War, many branches of medicine came under review as has already been mentioned. First Aid and resuscitation was one of those areas, and there was discussion over which techniques would be most effective for treating troops. An early example of this was Eve's rocking method. This method had been developed in adults, and during the war it was used along with other resuscitation techniques for adults, especially those under anaesthesia.[354] Frank Eve (1871-1952) regarded the thorax as 'a cylinder and piston', and he hoped to harness 'the piston action of the diaphragm' to resuscitate the patient.[355] During the World War II Eve worked alongside the Royal Navy to promote the use of his method.[356]

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Eve, F. (1933). "Actuation of the inert diaphragm by a gravity method." *Lancet* **1**: 995-997,
Killick, E. and F. Eve (1933). "Physiological investigation of the rocking method of artificial respiration." *Lancet* **1**: 740-742,
Hemingway, A. (1944). "An experimental study of different methods of artificial respiration." *BMJ*: p4355-4358,
Hemingway A, N. E. (1944). "A experimental study of different methods of artificial respiration." *BMJ*: 833-836.
Baskett, T. (2005). "Eve's rocking method of artificial respiration." *Resuscitation* **65**: 245-247.

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Eve, F. (1933). "Actuation of the inert diaphragm by a gravity method." *Lancet* **1**: 995-997.

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Baskett, T. (2005). "Eve's rocking method of artificial respiration." *Resuscitation* **65**: 245-247. p246.

After the War Eve's rocking method began to be applied to the asphyxiated newborn, with some clinicians modifying incubators to incorporate the technique.[357] Clinicians developed tilting tables which were used in resuscitation. The infant was placed in a bassinette or trestle which was rocked up and down. This allowed the weight of the liver and abdominal contents to drop downward and thereby pull air into the lungs when the head was up and the feet down, and when reversed it caused the expiration of air from the lungs.

Eve's rocking method gained widespread popularity during the late 1940s and 1950s, with variations on the rocker being constructed by individual clinicians or with the help of private engineering firms. Two London clinicians worked alongside RB Production and Engineering Co., Bridlington, to develop an electrical rocker which also supplied oxygen like an incubator.[358] The device was used to treat 'all caesarean sections, all assisted breech deliveries, all forceps deliveries under general anaesthetic, and for babies born in blue asphyxia', in the latter case when the infant had made no attempt at respiration.[359]

The Rocking method remained popular throughout the early 1950s, though appears to have gone out of use by the 1960s. Unlike some of the other resuscitative techniques, the rocking method was never directly condemned on the strength of controlled studies. Rather, it seems that it fell out of favour as the focus of resuscitators turned towards supplying oxygen and inflating the lungs, and as it became appreciated that the asphyxiated newborn was unlike an asphyxiated adult, because its lungs had never been expanded.[360]

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Millen, R. and J. Davies (1946). "See-saw resuscitator for the treatment of asphyxia in the newborn." *American Journal of Obstetrics and Gynaecology* **V52**: 508-509.
Millen, R., A. Rowsom, et al. (1955). "Prevention of neonatal asphyxia with the use of a rocking resuscitator." *American Journal of Obstetrics and Gynaecology* **v70**: 1087-1091.
Macintosh, R. and W. Mushin (1946). "Pulmonary exchange during artificial respiration." *BMJ*: 908-909.
Pavey, C. (1946). "Modification of the ericson and johnson resuscitator." *American Journal of Obstetrics and Gynaecology* **52**: 867-868.
Eve, F. and N. Forsyth (1948). "Asphyxia of the newborn treated by rocking." *BMJ*: 554-555.

358

Handley, D. and D. Handley (1951). "A rocker for asphyxia neonatorum." *BMJ*: 1282.

359

Ibid.

360

Cook, C., J. Lucey, et al. (1956c). "Medical progress: Apnea and respiratory distress in the newborn infant. Physiologic background, resuscitation and supportive technics." *NEJM* **254**(14): 651-657.

The trend of physiologists venturing into the clinic continued in the post-war years. This is evident in a second technique advocated for newborn resuscitation during the 1950s, electrophrenic stimulation. This technique was developed by the physiologist Kenneth Cross (1916-1990) at St Mary's Hospital Medical School, London. Cross became a very important figure in neonatal physiology throughout the 1950s and 1960s as he conducted both clinical and laboratory research on newborn respiration.[361]

Having studied the physiologist Stanley Sarnoff's research on phrenic nerve stimulation for resuscitation of adults, Cross worked with his colleague PW Roberts, from the physics department, to adapt the technique for application on asphyxiated newborns.[362] When stimulated the phrenic nerve produces contraction of the diaphragm and therefore aids in inflating and deflating the lungs. The technique involved placing electrodes on the newborn's neck and back, positioned to stimulate the phrenic nerve. Electrical pulses were then administered intermittently in an attempt to stimulate the diaphragm and therefore inflate the lungs by creating a negative intra-thoracic pressure. The technique had been employed in the University Hospital of Bonn for six months in 1927, and it had been claimed that there was no deaths due to birth asphyxia throughout that time.[363] This illustrates a degree of continuity of research from the interwar years.

Cross and Robert's study was in two parts. They initially had kept the apparatus at home and were called out to deliveries involving fetal distress or asphyxiated newborns at three London Hospitals, the Royal Postgraduate Medical School, Queen Charlotte's and St Mary's. This lasted for eleven months from May 1949. However they only successfully treated two cases, as the infants had either recovered or died by the time they arrived.[364] A grant from the MRC allowed Cross to spend time at the Rotunda Hospital in Dublin, which had an extremely high

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361 Kenneth Cross (1916-1990) was a physiologist based at St Mary's Hospital Medical School in London. During the 1950s and 1960s he became a world leader in neonatal respiratory physiology. His role in newborn resuscitation and respiratory physiology will be discussed in the remaining chapters.

362 Cross, K. W. and P. W. Roberts (1951). "Asphyxia neonatorum treated by electrical stimulation of the phrenic nerve." *BMJ*: 1043-1048.

363 [Anon] (1950). "Discussion on resuscitation of the newborn." *Proceedings of the Royal Society of Medicine* **43**(6): 443-452.

364 Cross, K. W. and P. W. Roberts (1951). "Asphyxia neonatorum treated by electrical stimulation of the phrenic nerve." *BMJ*: 1043-1048.

delivery rate. Within three months Cross was able to treat 29 cases, 25 of which recovered, during the second part of their study.[365]

Cross and Roberts found that there was a relationship between the current required to stimulate the diaphragm and the sickness of the infant, with a more anoxic baby requiring a higher stimulus.[366] They also argued that their research demonstrated that electrophrenic stimulation was capable of expanding the asphyxiated newborn's lungs, and it did not have the risks associated with positive pressure methods, which they claimed could cause pneumothorax or stomach inflation.[367] Although they admitted that their results could not 'give certain evidence of the efficacy of the method', they argued that: 'in the opinion of the clinicians responsible and the labour ward sisters, all those labelled severely ill were thought to be dying, yet five of the nine have lived'.[368]

Cross and Roberts were not claiming that their study confirmed the efficacy of the technique, or whether or not it would be practical in the clinical setting, but that the method should be developed and tested further against other techniques. At a time when there was still no consensus on the most appropriate newborn resuscitative technique, they felt that their experimental electrophrenic stimulation could be a viable treatment.

It would appear that their research met with some support across the Atlantic. Stanley Sarnoff, who had originally sparked Cross's interest in the technique, was equally impressed by the St Mary's team's research, which view he expressed in a letter to the *BMJ*.[369] Sarnoff claimed that he had collaborated with Professor Clement Smith at the Boston Lying-in Hospital, on the use of the treatment on the newborn. Smith was well respected in the emerging field of neonatology and had published the important textbook *The Physiology of the Newborn Infant* in 1945, as has already been mentioned. With Smith's encouragement Sarnoff had begun to

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365 Ibid.

366 Ibid.

367 Ibid.

368 Ibid.

369 Sarnoff, S. (1951). "Correspondence: Electrophrenic respiration in asphyxia neonatorum." *BMJ*: p1515.

train several house-officers at the Boston Lying-in Hospital to use the technique on asphyxiated newborns.[370] Sarnoff agreed that their technique avoided many of the risks associated with positive pressure inflation. However he wondered if the apparatus could be simplified enough to be feasible in the clinical setting.

There is little evidence that electrophrenic stimulation for newborn resuscitation ever got beyond this merely experimental stage. It was mentioned in reviews of newborn resuscitation up until the 1960s, and also in medical textbooks.[371] However, clinicians feared that the apparatus was too technical, although they often agreed that the research appeared encouraging and that theoretically it should prove effective.

The third example of a newborn resuscitation device which gained popularity during the 1950s was the Bloxsom Air Lock. This device was designed by the paediatrician Allan Bloxsom, at St Joseph’s Hospital in Houston, Texas. During the 1940s he had observed that most infants delivered by caesarean section suffered from birth asphyxia and required resuscitation.[372] From this observation he hypothesised that the uterine contractions during birth were necessary for the conditioning of the newborn for extra-uterine life. He believed that the contractions helped to empty the lungs of fluid, and had a direct stimulatory effect on the chest wall and lungs.[373] Bloxsom set about designing a device which would replicate the uterine contractions, and would therefore resuscitate the asphyxiated newborn. A prototype fashioned out of an old pressure cooker (figure 9) was constructed in 1950, and within a few years a clear plastic version was commercially available. The chamber was infused with humidified air and the pressure inside was cycled

370

Ibid.

371

Bullough, J. (1958). "Protracted foetal and neonatal asphyxia." *Lancet* **1**: 999-1000,
Abramson, H. (1960). *Resuscitation of the newborn infant: Principles and practice*. St Louis, The CV Mosby Company,
Abramson, H. (1966). *Resuscitation of the newborn infant and related emergency procedures*. St Louis, The CV Mosby Company.
Cook, C., J. Lucey, et al. (1956b). "Medical progress: Apnea and respiratory distress in the newborn infant (continued). Physiologic background, resuscitation and supportive technics." *NEJM* **254**(13): 604-610,
Donald, I. (1960). "Asphyxia neonatorum." *British Journal of Anaesthesia* **32**: 106-115.

372

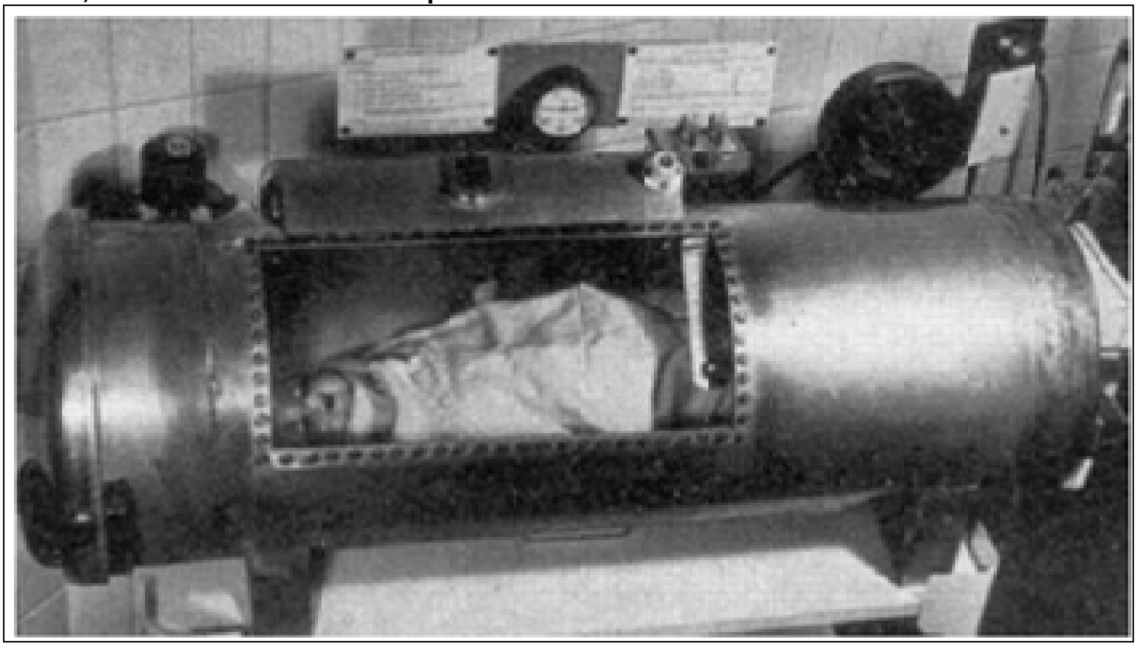
Bloxsom, A. (1942). "The difficulty in beginning respiration seen in infants delivered by cesarean section." *Journal of Pediatrics* **20**: 215-222.

373

Kendig, J. W., P. G. Maples, et al. (2001). "The bloxsom air lock: A historical perspective." *Pediatrics* **108**(6): e116.

between 1 and 3 pounds per square inch at one minute intervals.[374] As has been documented in an article by James Kendig and colleagues, the Air Lock gained rapid uptake in the US during the early 1950s. It was also rapidly employed in the new newborn nurseries which had been opened after the war for the treatment of respiratory distress. It received widespread news coverage, even appearing in *Newsweek*, heralded as the "Plexiglas Mother".[375]

Figure 8. Bloxom air lock. Image taken from Bloxsom (1950) 'Resuscitation of the newborn infnat', *Journal of Pediatrics* v 37 p311-319.



Like the older resuscitative techniques of the late nineteenth century, and also those newer techniques which had been introduced in the late 1920s, and heralded as 'scientific', the Bloxsom Air Lock was not subject to controlled clinical trials or animal studies. It was instead promoted on the basis of uncontrolled trials and one clinician's experience. Nevertheless there was rapid uptake of the technology throughout America, aided by mass advertising by the private company Loewensten Corporation who had produced a commercial Plexiglass model.[376] Supportive articles soon appeared in the medical press recounting successful

374 Bloxsom, A. (1950). "Resuscitation of the newborn infant: Use of the positive pressure oxygen-air lock." *Journal of Pediatrics* **37**: 311-319,
Bloxsom, A. (1951). "Asphyxia neonatorum: A new method of resuscitation." *JAMA* **146**(12): 1120-1124,
Kendig, J. W., P. G. Maples, et al. (2001). "The bloxsom air lock: A historical perspective." *Pediatrics* **108**(6): e116.

375 Kendig, J. W., P. G. Maples, et al. (2001). "The bloxsom air lock: A historical perspective." *Pediatrics* **108**(6): e116.

376 Ibid.

treatment using the Air Lock. As Dr Arthur Parmalee, a Beverly Hills paediatrician, commented in 1950:

> Dr Bloxsom's method accomplishes at least 2 things that are advantageous to the infant. First, it favors absorption of oxygen through the skin and mucous membranes of the upper respiratory tract, sufficient perhaps to tide the infant over until such time as respirations may spontaneously begin. Second, it certainly locks the infant up, safe from meddlesome and unintelligent treatment.[377]

Not everyone was as enchanted by the Air Lock and by the mid 1950s critics began to emerge. One of the most significant critiques was published by two obstetrical anaesthetists from Columbia University, Virginia Apgar and Joseph Kreiselman in 1953, both of whom, as has been mentioned, had a keen interest in newborn resuscitation.[378] They had conducted some physiological research on adult dogs and concluded that the use of the Air Lock did not benefit the asphyxiated animals. Bloxsom rebutted these criticisms, by claiming that the device had never been intended for use in dogs.[379]

However in 1956 a randomised controlled clinical trial, conducted at Johns Hopkins Hospital, found no difference between the mortality of two sets of infants, one group treated with the Air Lock and the other treated in a normal incubator.[380] As Kendig *et al* comment, the use of the Air Lock rapidly declined in the late 1950s, especially with the discovery of retrolental fibroplasia.[381] Kendig *et al*

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Bloxsom, A. (1951). "Asphyxia neonatorum: A new method of resuscitation." *JAMA* **146**(12): 1120-1124. Also cited in
Kendig, J. W., P. G. Maples, et al. (2001). "The bloxsom air lock: A historical perspective." *Pediatrics* **108**(6): e116.

378

Apgar, V. and J. Kreiselman (1953). "Studies on resuscitation. An experimental evaluation of the bloxsom air lock." *American Journal of Obstetrics and Gynecology* **65**(1): 45-52.

379

Kendig, J. W., P. G. Maples, et al. (2001). "The bloxsom air lock: A historical perspective." *Pediatrics* **108**(6): e116.

380

Reichelderfer, T. and H. Nitowsky (1956). "A controlled trial of the use of the bloxsom air lock." *Pediatrics* **18**: 918-927.

381

Kendig, J. W., P. G. Maples, et al. (2001). "The bloxsom air lock: A historical perspective." *Pediatrics* **108**(6): e116.
Retrolental fibroplasia was an iatrogenic disease discovered during the 1950s. It was linked to the uncontrolled use of oxygen to treat newborns, especially premature babies, which led to scarring of the retina and blindness due to oxygen toxicity. For a detailed history see:

conclude that the Bloxsom Air Lock was ‘an anomaly’, and presented its fate as one of an interesting aside in the progressivist narrative of the development of newborn care in the twentieth century.[382]

It is difficult to determine the wider landscape of newborn resuscitation during the 1950s, and gauge exactly what went on in different hospitals. However, as was mentioned in chapter 3, Canadian clinicians conducted a survey of 158 hospitals to ascertain their method of resuscitating the newborn in 1954.[383] The results illustrate the variety of different methods which were in use in Canadian Hospitals during the early 1950s. It found that hospitals varied in both the technique of resuscitation and the apparatus employed, with some using positive pressure resuscitators, others the Bloxsom Air Lock, electrophrenic stimulators and the various mask and bag resuscitating equipment. The Winnipeg group argued that this showed that no one machine had ‘yet proved satisfactory’.[384]

All of these examples illustrate some of the themes which the remainder of the thesis will explore. As Kendig *et al’*s article on the Bloxsom Air Lock illustrates, many of these short-lived resuscitative techniques have been relegated to mere ‘anomalies’, ‘setbacks’ or ‘misadventures’ in the positivist history of newborn resuscitation often recounted in contemporary medical textbooks or medical journal articles. It is hoped that the following chapters will provide a more detailed and sociologically enlightened analysis of this period in the history of neonatal resuscitation.

Silverman, W. (1980). *Retrolental fibroplasia: A modern parable.* New York & London, Grune and Stratton.

382 Kendig, J. W., P. G. Maples, et al. (2001). "The bloxsom air lock: A historical perspective." *Pediatrics* **108**(6): e116.

383 Schmidt, O., M. McLandress, et al. (1956). "An evaluation of infant resuscitation." *Canadian Medical Journal* **75**: 503-506.

384 Ibid. p506.

Positive-pressure inflation: face-mask versus endotracheal tube

As has already been discussed, by the Second World War there was general agreement that the asphyxiated newborn needed to be supplied with oxygen. However a variety of different techniques were developed to achieve this, some of which have been outlined in the previous section. A growing number of clinicians agreed that the most efficient and appropriate route for administering oxygen was via the mouth, through the trachea, to the lungs under positive pressure. However debate continued about whether this was best achieved using a face-mask or an endotracheal tube.

These debates first emerged during the interwar years when clinicians began to apply positive pressure methods to the asphyxiated newborn. However, they continued right through to the late 1960s. This section will examine these discussions as they first arose during the interwar years, and how they continued through the post-war period. A number of themes will emerge as the debates are analysed. Firstly, clinicians and physiologists became concerned with classifying the severity of asphyxia in each individual case, a trend which has been mentioned already. This move towards differentiating and classifying the degree of asphyxia became a point of contention when debating the most appropriate method of applying positive pressure ventilation to the newborn.

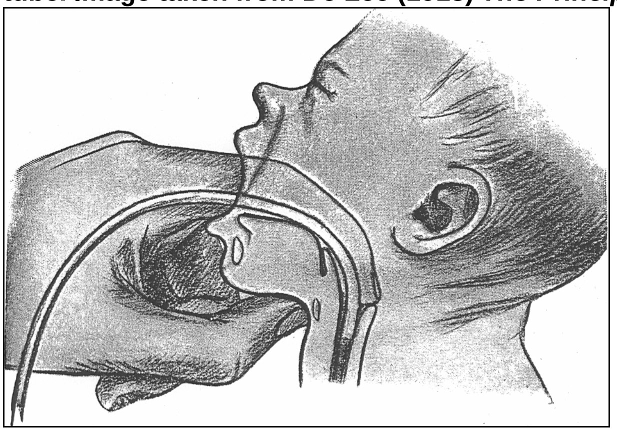
Secondly, there was a general concern about the safety of positive pressure methods. This issue was used not only to criticise the general use of positive pressure ventilation, but also to question the use of both the face-mask and the endotracheal tube. The third theme was linked to the accessibility of the techniques, with some fearing that endotracheal intubation was too specialist a skill for many to master. This is an issue which has already become apparent in earlier chapters.

Positive-pressure resuscitation during the interwar years

The use of a face-mask for newborn resuscitation had been popularised by Yandell Henderson, during the 1930s, as was discussed in chapter 2. Even though Henderson's method of using carbon dioxide for stimulating respiration had fallen out of favour, his use of a face-mask to supply positive pressure insufflation had remained popular and was further advocated by the anaesthetist Joseph Kreiselman during the 1940s.[385]

As has been mentioned, the use of an endotracheal tube with positive pressure insufflation for the resuscitation of the newborn was popularised during the interwar years. However, an earlier incarnation of the technique was advocated by the famous American obstetrician Joseph Bolivar De Lee (1869-1942) from the late nineteenth century.[386] De Lee described a method of 'blind' intubation, using the obstetrician's finger as a guide for introducing the endotracheal tube (see figure 10). The clinician then used his own breath to supply the positive pressure ventilation. However, this was just one of a number of different methods employed to treat the asphyxiated newborn during this period, and it does not appear to have become significantly popular.

Figure 9. De Lee's method of blind intubation, using the finger to guide the endotracheal tube. Image taken from De Lee (1913) *The Principles and Practice of Obstetrics.*



In 1928 the anaesthetist Paluel Flagg, who was introduced in chapter 2, first suggested using direct-vision endotracheal intubation and positive pressure insufflation in 1928 (see figure 5 p58).[387] He used a laryngoscope to insert the

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Kreiselman, J. (1943). "A new resuscitation apparatus." *Anesthesiology* **4**(6): 608-611, Kreiselman, J. (1945a). "The treatment of asphyxia." *Southern Medical Journal* **38**: 598-604, Kreiselman, J. (1945b). "The treatment of asphyxia." *Journal of the Connecticut Medical Society* **9**: 94-99,
Kreiselman, J. (1945c). "The treatment of asphyxia." *Anesthesiology* **6**(6): 654-655, Kreiselman, J. (1946). "The treatment of asphyxia." *Obstetrical and Gynecological Survey* **1**(2): 203-204.

386

DeLee, J. (1913). *The principles and practice of obstetrics, 1st edition*. Philadelphia and London, WB Saunders & Company.

387

Flagg, P. (1928). "Treatment of asphyxia in the newborn. A preliminary report of the practical application of modern scientific methods." *JAMA* **91**(11): 788-791.

endotracheal tube, and a rubber reservoir bag attached to a gas cylinder to provide the intermittent positive pressure. As was mentioned previously, Flagg was prompted to consider newborn resuscitation after reading an article by Henderson. He felt that Henderson's method could be improved by intubating the infant's trachea rather than using a face-mask.

The publication of Henderson and Flagg's methods, along with a number of other factors discussed in chapter 2, resulted in a series of reviews of newborn resuscitation during the 1930s and debates amongst clinicians regarding the applicability of both methods to the newborn. These discussions highlighted some of the main points of contention between supporters of the face-mask and supporters of the endotracheal tube.

As was discussed in chapter 2, physiologists had begun to change the clinician's understanding of the neonatal state, and they had contributed to a more physiologically-informed understanding of newborn asphyxia. This contributed to a growing concern about differentiating the severity of the individual cases of asphyxia neonatorum, and determining which cases required more active resuscitation. Some argued that not all infants required active resuscitation and that the mildly asphyxiated could easily be revived by simple clearing of the airways. It was thought that the more severely asphyxiated infant required some form of intervention beyond suctioning the airways.

Flagg was aware of this newer understanding of the asphyxiated newborn, and used this to claim that endotracheal intubation would be the most effective treatment. He had introduced a three-tier classification for asphyxiated newborns, which he thought was diagnostically more helpful than the traditional blue and white asphyxia.[388] Flagg's classification, which was discussed in the previous chapter, consisted of depressed, spastic and flaccid newborns. He argued that it was only the flaccid infant which required active resuscitation, which he believed was best achieved via intubation. He explained that these severely asphyxiated babies would have collapsed trachea, which blocked the passage of air or oxygen to the lungs. The introduction of an endotracheal tube ensured a patent airway and therefore ensured that the resuscitative gas reached the lungs. He stated that these infants could easily be identified by the absence of reflex reaction to

388 Ibid.

intubation. This trend, for differentiating those in urgent need of resuscitation and those who were mildly depressed, would continue throughout the mid-twentieth century, becoming of increasing importance during the 1950s and 1960s. Flagg stressed that the use of a face-mask could not guarantee a patent airway and was therefore not as effective as an endotracheal tube.

It is not unusual for identical innovations to occur around the same time in different areas, which is what happened during the interwar years in regards to newborn resuscitation.[389] Unknown to Flagg, and without knowledge of his work, two British obstetricians had also begun to apply the techniques of anaesthesia to the newborn. In March 1935 JB Blaikley and GF Gibberd published an important paper describing their method of tracheal intubation using a modified laryngoscope.[390] Blaikley and Gibberd, like Flagg, had been influenced by the work of Chevailier Jackson on adults, and employed a London based firm, Messrs, Down Bros, to make an infant sized laryngoscope.[391]

Blaikley and Gibberd shared Flagg's concerns that a face-mask was not the most effective means of supplying positive pressure ventilation for the severely asphyxiated baby. They believed that in the majority of cases simple methods of clearing airways and supplying oxygen and carbon dioxide would be enough to help the newborn initiate spontaneous respiration. However, sometimes there was a 'failure of this ideal atmosphere to reach the lungs', which could be due to blockage of the lower respiratory passages or due to flaccidity of the laryngeal strait as a result of severe asphyxia.[392] They therefore argued that the use of an

389 Historians and sociologists of science and technology have been interested in independent simultaneous scientific discoveries and inventions since the 1970s. A good introduction to the subject can be found in:
Merton, R. (1973). "Multiple discoveries as a strategic research site". in *The sociology of science*(Ed.). Chicago, The University of Chicago Press**:** 371-383.
For interesting case-studies of the phenomenon see:
Constant II, E. W. (1978). "On the diversity and co-evolution of technological multiples: Steam turbines and pelton water wheels." *Social Studies of Science* **8**(2): 183-210.
Or the more recent:
Burnham, J. C. (2008). "Accident proneness (unfallneigung): A classic case of simultaneous discovery/construction in psychology." *Science in Context* **21**: 99-118.

390 Blaikley, L. and G. Gibberd (1935). "Asphyxia neonatorum: It's treatment by tracheal intubation." *Lancet* **1**: 736-739.

391 Ibid. p737.

392 Ibid. p736.

intratracheal catheter was able to overcome both of these blockages, by allowing visualization and suction of the larynx and trachea, and also by maintaining the patency of the respiratory lumen. Blaikley and Gibberd felt that their method was more efficient and safer than the use of the face-mask or mouth-to-mouth methods, both of which ran 'the risk of distending the stomach' if the trachea was blocked.[393]

Endotracheal intubation with positive pressure insufflation did gather support in both the US and Britain during the interwar years. However, it still remained just one of several popular methods in use at the time, as discussed in chapter 2. Supporters of the method were drawn from anaesthetists, obstetricians and paediatricians. In 1935 Dr Watson-Williams wrote to the *Lancet* commenting that the method 'promises to be of great practical value', as it 'closely imitates what normally occurs shortly after birth'.[394] He felt that, in comparison to other techniques, such as spanking or swinging, this method bore more resemblance to the 'natural' inflation of the lungs.[395]

Similarly a 1937 review of newborn resuscitation, conducted by obstetricians from Brooklyn, agreed that endotracheal intubation was most effective for the severely asphyxiated newborns. Wilson *et al* viewed intubation as 'an extension of an inhalator' which ensured a clear and patent airway.[396] A 1936 review of newborn resuscitation in *JAMA* was also equally supportive of the technique.[397]

Support for endotracheal intubation also appeared in Britain during the late 1930s, with an editorial, 'Babies who do not breathe', in the *Lancet*.[398] The editorial stated that:

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393 Ibid. p737.

394 Watson-Williams, P. (1935). "Asphyxia neonatorum: Its treatment by tracheal intubation." *Lancet* **1**: 964.

395 Ibid.

396 Wilson, R., M. Torrey, et al. (1937). "The initiation of respiration in asphyxia neonatorum." *Surgery, Gynecology and Obstetrics* **65**(5): 601-622. p611.

397 McGrath, J. and K. Kuder (1936). "Resuscitation of the new-born." *JAMA* **106**(11): 885-890.

398 [Anon] (1938). "Babies who do not breathe." *Lancet* **2**: 731.

> The apparatus described is not particularly elaborate, and a little practice on the cadaver should quickly give obstetricians (or their anaesthetists, who are probably more experienced with intratracheal manipulations) the confidence required for following Flagg's programme.[399]

Further support for the technique was found in the letters from British clinicians published in the *Lancet* during the 1930s and 1940s. Douglas Belfrage lamented that:

> … in spite of their strong recommendations, and in spite of the still appallingly large numbers of babies lost through failure to breathe, there has been no general adoption of the treatment by intubation in this country.[400]

He further argued that the apparatus could be further simplified if the oxygen cylinder is substituted with the operator's own breath. This would mean that the apparatus could 'easily form part of an obstetric outfit', for both domiciliary and emergency care.[401] He claimed that the only difficulty was the passing of the endotracheal tube, arguing, however, that this would be overcome with some practice on a cadaver.[402]

Not everyone agreed that endotracheal intubation was appropriate for use in the newborn. The technique immediately met with criticism that it was too dangerous and technically inaccessible to most clinicians. In 1929 two Portland-based obstetricians, Albert Mathieu and Albert Holman, felt that De Lee's original method of blind intubation was simpler than, and as effective as, the use of a laryngoscope.[403] They argued that the use of a rubber catheter for intubation was 'simple, cheap, easy to keep in order and easily accessible at all times'.[404] They further stated that the operator's own breath should be used instead of pressurised

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399 Ibid.

400 Belfrage, D. (1938). "Correspondence: Asphyxia neonatorum." *Lancet* **2**: 856-857.

401 Ibid.

402 Ibid.

403 Mathieu, A. and A. Holman (1929). "Resuscitation of the asphyxiated new-born." *JAMA* **92**(23): 1917-1918.

404 Ibid. p1917.

gas, as it could deliver the appropriate amounts of oxygen and carbon dioxide, and again simplified the technique.[405] Although they agreed with Flagg's method in principle, they felt he had over-complicated things, which made it inaccessible to many clinicians.

However, just as the technique had gathered some supporters, it also had its critics, illustrated by another letter published in the *Lancet* shortly after the editorial. A Dr MH Philips wrote to the journal condemning what he considered to be over-treatment and another fad in the care of the asphyxiated newborn.[406] Philips believed that the most effective treatment was the clearing of the airways, and advocated the suspension of the newborn by the feet to achieve this. He regarded intubation as 'modern and elaborate', and usually an unnecessary intervention.[407] Using historical examples from the writings of William Smellie, Philips stated that most 'experienced' obstetricians knew that 'the air-passages having been cleared, warmth and leaving alone are often all that is needed' to revive the asphyxiated newborn.[408] Other critics felt that the technique was too difficult to master, and out of the reach of the GPs and midwives who attended the majority of births in Britain.[409]

The advocates of endotracheal intubation were aware of these apprehensive views. Blaikley and Gibberd admitted that 'the difficulties in the introduction of the tracheal catheter and the possible dangers of rupture of the lung from uncontrolled pressures have been sufficient to prevent intratracheal insufflation from being widely used'.[410] However, they felt that the direct-vision laryngoscope

405 Ibid. p1917.

406 Phillips, M. (1938). "Correspondence: Asphyxia neonatorum." *Lancet* **2**: 916.

407 Ibid.

408 Ibid.

409 Leak, W. (1941). "Correspondence: Treatment of asphyxia neonatorum." *Lancet* **1**: 433. [Anon] (1941). "Treatment of asphyxia neonatorum." *Lancet* **1**: 355-356.

410 Blaikley, L. and G. Gibberd (1935). "Asphyxia neonatorum: It's treatment by tracheal intubation." *Lancet* **1**: 736-739. p737.

circumvented these difficulties and 'enable[d] anyone to intubate the trachea with ease'.[411]

There was also a more general concern surrounding the safety of positive pressure methods. These fears were even evident amongst supporters of the two methods. Wilson *et al* feared that the use of intermittent positive pressure could inhibit the infant's own attempts at respiration and were unsure if it should be used actively to inflate the lungs under pressure.[412] Instead they thought that it might help to trigger the Hering-Breuer reflex.[413] Equally, Dr Watson-Williams questioned Blaikley and Gibberd's claims that up to 30cm of water pressure could be used safely on the asphyxiated newborn's lungs.[414]

Blaikley and Gibberd attempted to address these concerns over the use of positive pressure ventilation. They had conducted extensive studies to measure the normal pressures created by a healthy newborn during its first breaths. They found that a four pound infant should be treated with a number 3 catheter with a pressure of 32 centimetres of water, to get a 15 centimetres of water pressure in the bronchi, whereas a seven pound infant should be treated with a number 4 catheter and a pressure of 31 centimetres of water to get the equivalent pressure in the bronchi.[415] Although they felt that these pressures ensured the safety of the technique, they further stressed that the chest wall provided enough resistance to prevent damage due to any sudden expansion of the lungs in the newborn.[416] Despite these assurances, these concerns continued to be discussed well into the 1950s.

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411 Ibid. p737.

412 Wilson, R., M. Torrey, et al. (1937). "The initiation of respiration in asphyxia neonatorum." *Surgery, Gynecology and Obstetrics* **65**(5): 601-622. p610.

413 Ibid. p611.
The Hering-Breuer reflex refers to the action of the stretch receptors in the lung which prevent over-inflation and help to regulate normal rhythmic ventilation.

414 Watson-Williams, P. (1935). "Asphyxia neonatorum: Its treatment by tracheal intubation." *Lancet* **1**: 964.

415 Blaikley, L. and G. Gibberd (1935). "Asphyxia neonatorum: It's treatment by tracheal intubation." *Lancet* **1**: 736-739. p738.

416 Ibid. p738.

Positive pressure ventilation after World War II

As has been discussed, the interest in using positive pressure ventilation for newborn resuscitation continued after the Second World War. This continued interest was accompanied by continued debates surrounding both the choice of method and its relative safety. There was increased discussion over the differentiation of cases of asphyxia neonatorum, and clinicians increasingly considered there was a need for different methods to treat the more severely asphyxiated babies. Concerns over the danger of positive pressure resuscitation also continued after the war, and soon clinicians began to conduct research to determine the pressures required to inflate the lungs of the healthy newborn.

During the late 1940s Dr Hilda Roberts, an anaesthetist at the Royal Postgraduate Medical School, London, who was mentioned in chapter 3, emerged as a strong proponent of intubation and intermittent positive pressure insufflation for the asphyxiated newborn. She published an article in the *Journal of Obstetrics and Gynaecology of the British Empire* in 1949, which spelled out the resuscitation routine practiced at Hammersmith.[417]

There were four essential components to her regime: aspiration; intubation; oxygenation; and maintenance of circulation.[418] Like Blaikley and Gibberd, Roberts stressed the importance of aspiration, as it ensured a clear airway, which she regarded as ‘the deciding factor with regard to the success of the other methods applied to revive the infant’.[419] She advocated the use of a laryngoscope to allow clearing of the glottis and trachea under direct vision, which she argued ‘will often prove a life-saving measure’.[420]

Roberts then advocated the use of direct vision endotracheal intubation and claimed that paediatricians, obstetricians and anaesthetists should all be capable

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417 Roberts, H. (1949). "An anaesthetists contribution to the resuscitation of the newborn." *BJOG: An International Journal of Obstetrics and Gynaecology* **56**(6): 961-970.

418 Ibid. p964-968.

419 Ibid. p964.

420 Ibid. p964.

of performing this 'simple' procedure.[421] She felt that, once the anatomy and manipulation of the laryngoscope were mastered, the technique was simple and added that it was further simplified by the fact that a flaccid newborn presented no resistance to intubation, and that if the infant objected then it did not require intubation.[422] She stressed the importance of using the laryngoscope, which she argued would prevent oesophageal intubation, which she feared was a common occurrence in the past.[423]

Robert's article highlights the continuity in the debates surrounding positive pressure methods from the interwar years through to the post-war period. Clinicians and physiologists continued to attempt to differentiate the severity of cases of asphyxia and to consider whether or not these different degrees of asphyxia neonatorum required different treatment. By the 1950s those who supported endotracheal intubation increasingly argued that this method was most effective for the treatment of the severely asphyxiated baby, who was suffering from asphyxia pallida and appeared flaccid with a slowly or non-existed heart beat. They believed that the mildly asphyxiated newborn could be treated using a face-mask as they did not have the added problem of a flaccid trachea. Roberts argued that the endotracheal tube was the most effective method for the severe cases, although it was not always necessary. She stated that oxygen could equally be provided via a face mask with a reservoir bag connected to an oxygen supply, if the infant was mildly asphyxiated.[424]

In 1952 Roberts published the results of a trial conducted on severely asphyxiated newborns treated with intubation and insufflation.[425] She had treated 66 'severely asphyxiated infants using endotracheal insufflation with oxygen' from 1949 to

421 Ibid. p964.

422 Ibid. p964.

423 Ibid. p964.

424 Ibid. p965.
Blaikley, L. and G. Gibberd (1935). "Asphyxia neonatorum." *Lancet* **1**: 736.

425 O'Brien, D. and H. Roberts (1952). "Endotracheal insufflation with oxygen in the treatment of asphyxia neonatorum." *BMJ*: 963-964.

1951.[426] Intermittent positive pressure at 20 centimetres of water at 10-15 per minute was then administered with oxygen and she reported only 14 deaths.[427]

Gibberd and Blaikley continued to advocate intubation with positive pressure inflation as the most effective treatment for the severely asphyxiated newborn during the 1950s. The pair had been employing endotracheal intubation with insufflation for newborn resuscitation for 17 years when they presented a short paper at the Royal Society of Medicine's Section on Obstetrics and Gynaecology in 1950.[428] They stressed that this technique was reserved for those infants with severe asphyxia, who presented as limp with a failing heart beat, that is, those suffering from asphyxia pallida.[429] Blaikley argued that 'unless prompt measures are taken some of these babies will die'.[430]

Aware of the continued concern surrounding the safety of the technique, Blaikley made a point of emphasizing that he had never had, or was aware of, any 'accident' with the technique over its 17 years of use at Guy's Hospital, London.[431] He further defended his use of intubation by arguing that it avoided the risk of inflating the stomach which commonly occurred when a face-mask was used to treat such cases. Blaikley explained that inflating the stomach could trick the operator into thinking that the chest was being inflated or that it could obstruct the diaphragm.

Further support for the use of intubation and intermittent positive pressure ventilation was published in *JAMA* in 1953.[432] Again, this article, by obstetrician John Mann, University of Toronto, argued that the method was of particular use in

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426 Ibid. p963.

427 Ibid. p963.

428 [Anon] (1950). "Discussion on resuscitation of the newborn." *Proceedings of the Royal Society of Medicine* **43**(6): 443-452.

429 Ibid. p448.

430 Ibid. p448.

431 Ibid. p448.

432 Mann, J. (1953). "Method and machine for resuscitation of the newborn." *JAMA* **152**(14): 1333-1335.

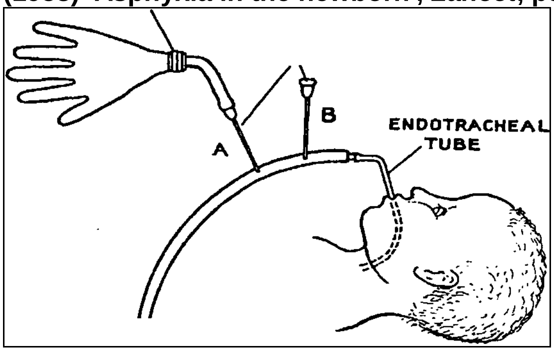
cases of severe asphyxia, when a face-mask was inadequate.[433] He argued that the ‘controversy over the ease and safety of intubation’ was due to ‘a gross misunderstanding of the problem’, arguing that difficulty often lay in the use of bad technique.[434] Operators often hyper-extended the infant’s neck, which Mann argued did not allow visualisation of the glottis.

However, scepticism still remained in Britain and prevented widespread adoption of the method. As one clinician remarked in 1953:

> For the immediate and certain relief of asphyxia of the newborn, endotracheal intubation followed by inflation, using a rebreathing bag, is a method which is not, I think, used sufficiently.[435]

As already mentioned, one reason was the concern that it was too complicated to be employed by GP’s and midwives who attended a large proportion of births in domiciliary practice. Some supporters of the use of intubation attempted to address this concern during the 1950s. Clinicians designed simple devices which they thought could be employed easily by the general practitioner or midwife to treat the asphyxiated newborn. Noel Jackson, a clinician from Watford, published his ad-hoc method of resuscitating a newborn in the *Lancet* in 1953.[436] Jackson had created a makeshift re-breathing bag using a surgeon’s glove, which could be quickly and easily constructed if an anaesthetist’s reservoir bag was not available (see figure 11). He also advocated the use of a rubber catheter.

Figure 10. Noel Jackson's ad-hoc intermittent positive pressure device. Image from Jackson (1953) 'Asphyxia in the newborn', *Lancet*, p834.



433 Ibid.

434 Ibid. p1333.

435 Jackson, J. (1953b). "Correspondence: Asphyxia in the newborn." *Lancet* **2**: 1046.

436 Jackson, J. (1953a). "Correspondence: Asphyxia in the newborn." *Lancet* **2**: 834.

Another ad-hoc resuscitation apparatus was described by an anaesthetist, N Wulfsen, in Johannesburg in 1955, again illustrating an awareness that not all birth attendants would have the specialist anaesthetic equipment at hand.[437] Like Jackson, Wulfsen had made use of a surgical glove and adapted it to act as a reservoir bag. He advocated intubating the infant nasally, then attaching the catheter to a valve which was then connected to the glove, which was connected to an oxygen supply. Wulfsen explained that the apparatus was ‘simple and suitable for use by a nurse’.[438]

In a bid to address the concerns over the use and safety of positive pressure resuscitation during the early 1950s, the Brooklyn-based paediatrician Richard Day, who worked alongside Virginia Apgar, began to investigate pressure-time relations needed to inflate atelectatic lungs of animals safely.[439] Having observed the respiration rate and depth of the normal infant, Day hypothesized that the infant was able to use higher positive-pressure differentials to inflate its lung by applying the pressures for short periods of time. He therefore advocated the use of high positive pressures, up to 40 cm of water, over short intervals of 0.15 seconds, for the resuscitation of asphyxiated newborns.[440]

Day presented his research at the 104th annual meeting of the America Medical Association in 1955.[441] He argued that short duration pressures had two further advantages: they caused less impairment of venous return and also ‘decreased the amount of expansion of easily expandable parts of the lungs as compared with that of the more resistant areas’, therefore allowing more uniform expansion.[442]

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437 Wulfsohn, N. (1955). "A simple apparatus for resuscitation of the newborn." *BJOG: An International Journal of Obstetrics and Gynaecology* **62**(4): 612-613.

438 Ibid.

439 Day, R., A. Goodfellow, et al. (1952). "Pressure-time relationship in the safe correction of atelectasis in animal lungs." *Pediatrics, Springfield* **10**: 593-.
Day’s research was mentioned briefly in chapter 3.

440 Ibid.

441 Day, R. (1955). "Expansion of the lungs of newborn infants." *JAMA* **159**(14): 1340-1341.

442 Ibid. p1340.

Referring to the work of his colleague Apgar, Day stated that a tracheal catheter could be used to safely administer up to 50 centimetres of water.[443] Day stressed that individual operators should practice with their own tubes on stillbirths. He argued that clinicians should have a good physiological understanding of the newborn and pleaded that if positive pressure methods were going to be used that they should be applied ‘as physiologically as possible’, by imitating an infant’s own efforts.[444]

Days’ research was supported by a Michigan paediatrician, James Wilson, who published an article in *Pediatrics* which further highlighted the continued concerns surrounding the use of positive pressure ventilation during the 1950s.[445] Wilson had studied the factors involved in alveolar rupture when using a mechanical aid to respiration or resuscitation. He found that the degree of damage was dependent on the degree of pressure, the time it was applied, and the proportion of total lung volume which was expandable.[446]

Day’s research provided a boost to those who advocated the use of positive pressure resuscitative methods, either using an endotracheal tube or a face-mask. It was of particular interest to a group of private sector researchers in the US, who had been developing their own device for providing positive pressure insufflation to the asphyxiated newborn during the 1950s.

In the US the issue of newborn resuscitation, which had sporadically come to the attention of private engineering companies in Britain already, became of interest to the newly established Paediatric Research Laboratory of the private research institution, the Lovelace Foundation, based in New Mexico. By the beginning of the 1950s the Lovelace Foundation was a major contractor to the United States government in the field of research into the biological effects of nuclear weapons and also conducted research into medical aerospace technology and aviation medicine. In 1952 a multidisciplinary team headed by Roy Goddard, Director of the

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443 Ibid.

444 Ibid. p1341.

445 Wilson, J. (1954). "Factors involved in the production of alveolar rupture with mechanical aids to respiration." *Pediatrics* **13**: 146-149.

446 Ibid. p149.

Paediatric Research Laboratory, began to develop an infant resuscitator.[447] The research was divided between two teams, the clinical team, which included obstetricians, paediatricians and anaesthesiologists, and the investigative team, which included the above medical specialists and also pathologists, physiologists, engineers, surgeons, otolaryngologists and neurologists.

In an article in *American Journal of Diseases of Children* Goddard described the factors which had encouraged the Lovelace foundation to tackle newborn resuscitation. He explained how they had become aware that, although infant mortality had been greatly reduced over the previous 40 years, the first 24 hours of life had a persistently high mortality rate.[448] Further investigation had revealed that 'anoxia and abnormal pulmonary pathology constitute[d] 59 per cent' of all neonatal deaths.[449] An awareness that babies became sluggish and took longer to breathe due to obstetric anaesthesia led the researchers to consider these infants as a new group of infants requiring resuscitation.[450] Goddard and his team had therefore identified three groups of infants in need of resuscitation[451]:

1) A baby who is unable to expand its lungs by its own effort;

2) A baby who breathes spontaneously but still suffers partial atelectasis;

3) An anoxic baby, often affected by maternal anaesthesia, which benefits from the administration of oxygen.

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447 Goddard, R. (1955). "The role of an infant resuscitation team in investigative studies of respiratory onset at birth." *Current Researches in Anaesthesia and Analgesia* **34**(1): 1-25-, Goddard, R. and V. Bennett (1955). "Newer concepts of infant resuscitation and positive-pressure therapy in pediatrics." *American Journal of Diseases of Children* **89**(1): 70-97.

448 Goddard, R. and V. Bennett (1955). "Newer concepts of infant resuscitation and positive-pressure therapy in pediatrics." *American Journal of Diseases of Children* **89**(1): 70-97. p70.

449 Goddard, R. (1955). "The role of an infant resuscitation team in investigative studies of respiratory onset at birth." *Current Researches in Anaesthesia and Analgesia* **34**(1): 1-25-. p1.

450 Ibid. p1.

451 Goddard, R. and V. Bennett (1955). "Newer concepts of infant resuscitation and positive-pressure therapy in pediatrics." *American Journal of Diseases of Children* **89**(1): 70-97. p72. Goddard, R. (1955). "The role of an infant resuscitation team in investigative studies of respiratory onset at birth." *Current Researches in Anaesthesia and Analgesia* **34**(1): 1-25-. p1.

Infants were assessed 60 seconds after birth using the Apgar score, and if unsatisfactory, resuscitation was started. Goddard explained that those with an intact nervous system mechanism will respond quickly and begin normal respiratory rhythms. However if the central nervous system mechanism is damaged there will be a delay in the onset of rhythmic respiration and 'these infants need to have respiration established'. [452] Goddard claimed that: 'The greatest challenge today in infant resuscitation is the inflation of the unexpanded lungs of the infant who exerts no respiratory effort, or is unable to expand his own lungs.'[453] The second important group were those infants who breathed but suffered partial atelectasis i.e. those which suffered respiratory distress.[454] It was with these two categories in mind that the Lovelace team began to investigate newborn resuscitation.

The two teams established six objectives for the development of an infant resuscitator[455]:

1. It had to expand unexpanded/atelectatic lungs of newborn who fail to breathe.

2. It should correct partial atelectasis in newborns with respiratory distress.

3. It should oxygenate anoxic newborns, but be able to vary the gas mixtures.

4. It should be able to deliver moisture.

5. It should promote respiratory drainage.

6. It should be simple and available.

Referring to previous research on infant resuscitation, the Lovelace team decided that intermittent positive pressure seemed the most logical resuscitative method.

452 Goddard, R. (1955). "The role of an infant resuscitation team in investigative studies of respiratory onset at birth." *Current Researches in Anaesthesia and Analgesia* **34**(1): 1-25-. p4.

453 Ibid. p4.

454 Ibid. p5.

455 Goddard, R. and V. Bennett (1955). "Newer concepts of infant resuscitation and positive-pressure therapy in pediatrics." *American Journal of Diseases of Children* **89**(1): 70-97. p74.

They conducted a wide array of animal studies and used an artificial rubber lung to determine the best pressures and also the optimum time these pressures should be applied. However they soon decided that these tests were inadequate and that only the true infant lung would be acceptable for the research, so they began to conduct post-mortem studies.

Although they admitted that the optimal pressure still remained a mystery, they determined that ‘patchy aeration occurs in the human infant lung when a positive pressure of 30 cm of water is applied over a 0.2 second interval’.[456] They argued that higher pressures should be used initially at short intervals, which would give more uniform expansion. Following this initial expansion, lower pressures should be employed to avoid damage to the expanded lung.[457]

Based on these observations they developed the Goddard-Bennett-Lovelace (GBL) infant hand resuscitator, which used a face mask attached to a reservoir bag, which could be used to employ intermittent positive pressure ventilation (see figure 12 & 13 below). They also developed a set of resuscitation principles. All infants would immediately have their upper airways cleared and the operator would ensure they had a patent airway. Infants would be kept warm with blankets and within two minutes intermittent positive pressure using the GBL resuscitator and pressurised oxygen would be applied to expand the lungs. Initially a pressure of 50-60 centimetres of water would be given for 0.2-0.3 seconds for between 12-24 impulses, allowing an expiratory interval of 0.4-0.8 seconds.[458] If the lungs appeared to be expanding pressure would be reduced to 40cm of water for 12-24 impulses and then reduced further to 20-30 centimetres.[459]

456 Goddard, R. (1955). "The role of an infant resuscitation team in investigative studies of respiratory onset at birth." *Current Researches in Anaesthesia and Analgesia* **34**(1): 1-25-. p11.

457 Ibid. p11.

458 Ibid. p21.

459 Ibid. p21.

Figure 11. Image of clinician using the GBL hand resuscitator. Image from Goddard (1955) *Current Researches in Anesthesia and Analgesia*, v34, p1-25.

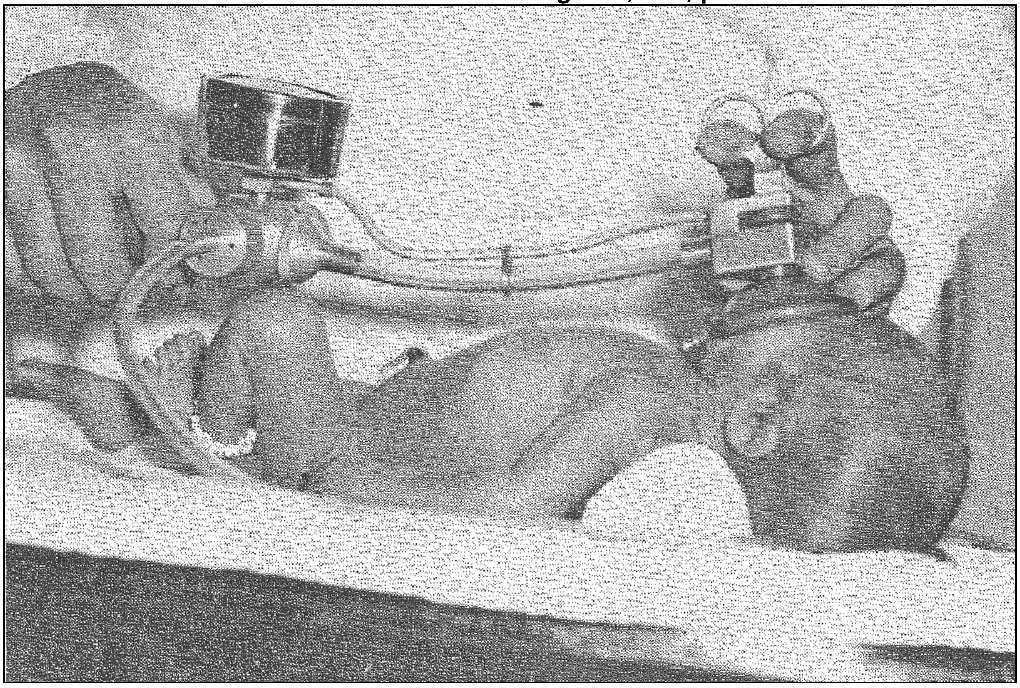
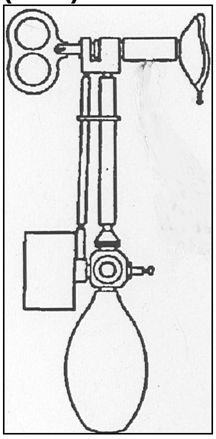


Figure 12. Diagram of the GBL hand resuscitator, composed of a face-mask and the squeezable bag for administering intermittent positive pressure. Adapted from Goddard (1955) *Current Researches in Anesthesia and Analgesia*, v34, p1-25.



Goddard claimed that in the majority of cases one or two impulses would suffice to initiate respiration, and most of the other infants respond with twenty minutes.[460] Those who failed to respond within this time often suffered from severe intracranial haemorrhage or congenital defects. He stated that his team had intubated less than ten per cent of infants, as the 'high pressures applied via the face piece [were] … sufficient for expansion to be achieved and thus avert possible damage to the upper respiratory tract.'[461] He claimed that they had no problem with inflation

460 Ibid. p22.

461 Ibid. p22.

of the stomach, and that gentle pressure on the abdomen could rectify this anyway. He also stated that they had no cases of pneumothorax.[462]

The Lovelace Foundation had few births to work with, with only 1,143 in 27 months from 1952 to 1954, and only 84 of these infants required resuscitation.[463] However of those who were resuscitated 69, or 82 per cent, survived. Goddard was aware that although this result was favourable it was not enough to advocate widespread use of the GBL resuscitator.[464] He therefore stated that a larger clinical trial of the apparatus was required, which they were in the process of doing with the help of several other hospitals. However, by 1955 Goddard and his team had already begun attending conferences and promoting their apparatus amongst paediatricians, anaesthetists and obstetricians.[465]

Reviews of newborn resuscitation during the mid-1950s reflect the growing support for positive pressure resuscitation. In 1956 a series of three articles was published in the *NEJM*, arguably the most influential medical journal in America.[466] The three articles presented a review of the current understanding of apnoea and respiratory distress in the newborn, including discussion of physiological research and also developments in resuscitation. They were written by clinicians from one of the leading research groups on neonatal care at the time, from Harvard.[467] The group, which included Charles Cook, the Professor of Paediatrics, and Clement Smith, who worked at the Boston Lying-in Hospital and Children's hospital, agreed

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462 Ibid. p22.

463 Ibid. p23.

464 Ibid. p23.

465 In 1954 Goddard gave papers at both the 103rd Annual meeting of the American Medical Association in San Francisco and also the 29th Congress of Anaesthetists in Los Angeles.

466 Cook, C., J. Lucey, et al. (1956a). "Medical progress: Apnea and respiratory distress in the newborn infant. Physiologic background, resuscitation and supportive technics." *NEJM* **254**(12): 562-568,
Cook, C., J. Lucey, et al. (1956b). "Medical progress: Apnea and respiratory distress in the newborn infant (continued). Physiologic background, resuscitation and supportive technics." *NEJM* **254**(13): 604-610,
Cook, C., J. Lucey, et al. (1956c). "Medical progress: Apnea and respiratory distress in the newborn infant. Physiologic background, resuscitation and supportive technics." *NEJM* **254**(14): 651-657.

467 This Harvard research group will be discussed in more detail in Chapter 5.

that intubation with positive pressure inflation was the most effective resuscitative method for the severely asphyxiated newborn.[468]

Another review of newborn resuscitation, by the anaesthetist VL Politi, was published in 1957.[469] Again this paper highlighted the growing familiarity of clinicians with the basic physiology, and an appreciation that an understanding of the physiology was needed to assess different techniques. Politi favoured the administration of oxygen under positive pressure for resuscitation, and suggested this was best given via a face mask with a small pharyngeal airway in place. However in the flaccid newborn, he advocated endotracheal intubation. Of all the methods available to supply positive pressure, Politi favoured the simpler techniques such as the manual GBL infant hand resuscitator, which had a reservoir bag attached, mouth-to-mask method or the mouth-to-tube technique.[470]

As has been mentioned before, it is difficult to gain a detailed impression of the popularity of newborn resuscitation devices during this period in the US and UK. However, a review of the medical textbooks for the 1950s can provide some insight. What becomes apparent is that although the positive pressure techniques did gain growing popularity in medical journals, they were still considered just one of a number of potential methods suggested in medical textbooks.

However, by the mid-1950s there did appear to be some degree of consensus on the sort of regime for treating the asphyxiated newborn emerging.[471] All the

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468 Cook, C., J. Lucey, et al. (1956c). "Medical progress: Apnea and respiratory distress in the newborn infant. Physiologic background, resuscitation and supportive technics." *NEJM* **254**(14): 651-657.

469 Politi, V. (1957). "Resuscitation of the newborn." *Canadian Anaesthetist's Society Journal* **4**(2): 118-125.

470 Ibid. p122-123.

471 Sheldon, W. (1951). *Diseases of infancy and childhood*. London, J &A Churchill Ltd,
Hughes, J. (1952). *Pediatrics in general practice*. New York, Toronto & London, McGraw-Hill Book Company, Inc.
Gaisford, W. (1953). "Care of the newborn baby". in *Paediatrics for the practitioner. Vol1*. W. Gaisford and R. Lightwood (Ed.). London, Butterworth & Co. (Publishers), Ltd. **1:** 53-85,
Parsons, L., S. Barling, et al. (1954). *Diseases of infancy and childhood, 2nd edition*. London, New York & Toronto, Oxford University Press,
Greenhill, J. (1955). *Principles and practice of obstetrics*. Philadelphia & London, WB Saunders,
Sheldon, W. (1955). *Diseases of infancy and childhood*. London, J & A Churchill Ltd.
Paterson, D. and J. McCready (1956). *Pediatrics*. Philadelphia & Montreal, JB Lippincott Company.
Schaffer, A. (1960). *Diseases of the newborn*. Philadelphia & London, WB Saunders Co.

textbooks agreed that immediate care should involve clearing the infant's airways by suctioning, keeping the infant warm, and then assessing the degree of asphyxia. By the end of the decade it appeared that there was general acceptance that Virginia Apgar's scoring method was very useful for this. Those infants deemed to be suffering from mild asphyxia were generally treated by further suctioning of the airways and sometimes with inhalation of oxygen or simply being placed in an incubator. However, those with the lower Apgar scores, deemed to be more severely asphyxiated were judged to require more active resuscitation.

Despite this emerging consensus there were still some areas of contention. Those who supported endotracheal intubation generally agreed that the face-mask was adequate for mildly depressed infants. However they argued that the severely asphyxiated baby, with a flaccid airway would not be successfully treated by this method. They claimed that an endotracheal tube was needed to ensure a patent airway. However, others, such as the Lovelace researchers, contended that intubation was unnecessary, with high enough pressure applied over short time intervals a face mask and reservoir bag could effectively treat even the severely asphyxiated newborn.

This conflict was not restricted to supporters of positive pressure methods. As can be seen in the medical textbooks, other methods of resuscitation were also advocated during the mid to late 1950s, including Eve's rocking method and the Bloxsom Air Lock, which have been discussed already, as well as negative pressure methods such as the Drinker apparatus. However, the positive pressure method did achieve growing popularity towards the end of the decade.

The remainder of the thesis will look at how the formation of networks of clinicians and physiologists during the late 1950s and 1960s contributed to the more widespread use of positive pressure methods and also the fates of two other resuscitative techniques: intragastric oxygen, and hyperbaric oxygen. The role of these networks in the history of newborn resuscitation during the mid-twentieth century, and also more generally in the development of the sub-specialty of neonatology, will become more apparent through the use of these case studies.

The following chapter will introduce and describe the formation and constitution of this network during the 1950s. The remaining chapters will then analyse in greater depth the fates of intragastric oxygen, hyperbaric oxygen, and intubation with positive pressure, which were all used for newborn resuscitation during the 1950s and 1960s.

Chapter 5

Neonatal mortality after WWII and the identification of the asphyxiated newborn

One of the stimuli for the continued interest in the asphyxiated neonate after WWII was a concern over persistently high neonatal mortality in Britain and the United States. By the mid-1950s certain broad conclusions were evident regarding infant mortality in Britain. It was agreed that although infant mortality had been falling from the late nineteenth century, neonatal mortality had remained consistently high, and that these rates varied across Britain.[472] The main causes of death in the neonatal period were ‘immaturity, asphyxia and atelectasis, congenital malformations and birth injury’.[473] These conclusions were drawn mainly from vital statistics collected by the Registrar Generals in Great Britain. A handful of smaller local surveys were also carried out in the post-war period to investigate infant mortality. These included a survey of 5,000 infants by a Joint Committee of the Royal College of Obstetricians and Gynaecologists and the Population Investigation Committee in 1946, a social-medical survey conducted by James Spence in Newcastle-upon-Tyne in 1947, and a small study in Luton in 1945.[474] Most of these small-scale enquiries related infant mortality to social and environmental circumstances. However it was felt by some government statisticians that these enquiries were insufficient and they decided to mount a larger enquiry into infant morbidity and mortality in the first year of life during 1952-53, which resulted in a published report in 1957.[475]

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472 Grundy, F. and E. Lewis-Faning, Eds. (1957). *Morbidity and mortality in the first year of life*. Cardiff, The Eugenics Society. p11.

473 Ibid. p11.

474 Douglas, J. (1951). "Health and survival of infants in different social classes." *Lancet* **2**: 440.
Greenwood, M. (1949). “Annual report of the MOH Essex”. *Medical Oddicer* **81**: 115.
Lowe, C. and T. McKeown (1954). "Incidence of infectious diseases in the first three years of life, related to social circumstances." *British Journal of Preventative and Social Medicine* **8**: 24.
Spence, J. Walton, W. et al. (1954). *A thousand families in Newcastle-upon-Tyne*. Oxford, Oxford University Press.

475 Grundy, F. and E. Lewis-Faning, Eds. (1957). *Morbidity and mortality in the first year of life*. Cardiff, The Eugenics Society.

This survey collected data on the sickness suffered by infants during the first year of life and also details of factors involved in infant mortality.[476] These data were related to social statistics of the areas surveyed as well as clinical and social information on the infants and their families. The survey found strong links between infant mortality and social class, although there was variation across the different areas.[477] Neonatal mortality was highlighted as higher than post-natal mortality, although this was not the main emphasis of the survey. The survey concluded that the three leading causes of infant mortality were congenital malformations, immaturity and respiratory disease. It called for improved maternal and child care.[478]

Although there had been a handful of inquiries specifically concerned with the neonate from the late 1940s and early 1950s, it was still felt that little had been done to tackle the persistently high neonatal and perinatal mortality rates in Britain. By the mid-1950s the Ministry of Health and British clinicians were aware that although perinatal mortality had fallen sharply during the 1940s, this decline had not continued during the 1950s. It was also realised that the combined English and Welsh perinatal mortality rate was higher than many other countries. In 1955 it was 38.3 per 1000 births, in the Netherlands it was 29.2, in New Zealand it was 27.8, in Norway it was 25.9 and in the USA it was 30.4.[479] These figures convinced WCW Nixon, Professor of Obstetrics and Gynaecology at University College Hospital (UCH) in London, to approach the National Birthday Trust Fund in 1954 to ask if they would consider funding a study of the 'relative risks of hospital and home confinement' in relation to perinatal mortality.[480]

The National Birthday Trust was established in 1928 in response to the alarming high maternal mortality in Britain. It had conducted several maternal mortality surveys during the interwar years, campaigned for improved maternal and child

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476 Ibid. p17-18.

477 Ibid. p123.

478 Ibid. p124-130.

479 Williams, A. (1997). *Women & childbirth in the twentieth century. A history of the National Birthday Trust Fund 1928-93.* Gloucestershire, Sutton Publishing. p198.

480 Ibid. p198.

welfare and also pain-free births. With the rapid fall in maternal mortality by the 1950s, the Trust was able to turn its attention towards perinatal mortality. It agreed with Nixon that such a survey was necessary and established a steering committee in 1955, which included paediatricians, obstetricians and representatives from the Ministry of Health, the Welsh Board of Health, the Department of Health for Scotland, the Royal College of Obstetrics and Gynaecology, the Central Midwives Board, the Royal College of Midwives, the British Paediatric Association and the Royal College of General Practitioners.[481] Neville Butler, a paediatrician from UCH, was selected as Director of the survey.

It was decided that the scope and aims of the survey should be widened to investigate: 'how and where British babies are born or die, how often and with what clinico-pathological associations, and thus what can be done to reduce perinatal mortality'.[482] They hoped this would provide:

> …easy reference to perinatal mortality risks for different maternal ages, parities, social groups and according to other factors known at the time the mother books [into hospital], and also those abnormalities developing throughout pregnancy and during labour.[483]

The Survey was conducted in 1958, and included all births in Britain within one week between 3rd and 9th of March. Midwives interviewed mothers and all clinical information from available records and medical staff was also recorded on the questionnaires. An important aspect of the Survey was the addition of pathological information from autopsies of 'all stillbirths and babies who died in the first week of life through the months of March, April and May'.[484] By the end of 1958 there were 25, 000 complete questionnaires ready for analysis.[485] The analysis of the data

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481 Pp/nbt/m/1: Draft letter from the chairman of the technical advisory committee to the national birthday trust, undated. *National Birthday Trust Archives [PP/NBT]. Archives and Manuscripts, Wellcome Library.* London.

482 Butler, N. and D. Bonham (1963). *Perinatal Mortality. The first report of the 1958 British perinatal mortality survey under the auspices of the National Birthday Trust Fund*. Edinburgh and London, E & S Livingstone Ltd. pix.

483 Ibid. p ix.

484 Williams, A. (1997). *Women & childbirth in the twentieth century. A history of the National Birthday Trust Fund 1928-93.* Gloucestershire, Sutton Publishing.p 208.

485 Butler, N. and D. Bonham (1963). *Perinatal mortality. The first report of the 1958 british perinatal mortality survey under the auspices of the national birthday trust fund.* Edinburgh and London, E & S Livingstone Ltd. p x.

proved extremely arduous and time-consuming, and the first report was not published until 1963.[486]

The Survey received widespread publicity in 1958 in a bid to gain public support and compliance. The Trust sent press releases to national and local papers and woman's magazines from early 1958, and representatives of the survey team were interviewed on both television and print.[487] The publication of the first report also received widespread media coverage. A press conference was held on 25th October 1962, where Butler presented some of the key findings of the survey. Most significant for this thesis was that Butler highlighted deaths due to birth asphyxia, stating:

> Clearly the baby deaths from abnormalities could not immediately be reduced, but the Survey showed that something could be done for the large group of babies which had been found to die from lack of oxygen just before or after labour. Asphyxia formed one in three of all deaths; they were more frequent and accounted for 8000 deaths in this country. The babies concerned were quite normal, apart from asphyxia, and if they could be saved from this condition they would grow up healthy people.[488]

This statement was picked up by the press which ran shocking headlines and stories in the papers the following day. Headlines included: 'Need so many babies die?'; '25, 000 babies die when born. Survey may improve maternity service'; 'The babies who need not have died'; 'Thousands of babies need not have died'; 'Crisis in childbirth!'; and 'The dangerous day in human life'.[489] The problem of birth

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Ibid. A summary of the findings of the first report can be found in:
Williams, A. (1997). *Women & childbirth in the twentieth century. A history of the national birthday trust fund 1928-93.* Gloucestershire, Sutton Publishing. p214.

487

Pp/nbt/m/11/1: Publicity folder including press releases and press clipping, 1957-58. *National Birthday Trust Archives [PP/NBT]. Archives and Manuscripts, Wellcome Library.* London.

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Butler, N. (1962). Pp/nbt/m/11/2/1: Transcript of the national birthday trust press conference, 25th oct 1962. *National Birthday Trust Archives [PP/NBT] Archives and Manuscripts, Wellcome Library*. London.

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[Anon] (1962). "25,000 babies die when born. Survey may improve maternity service." *Evening Dispatch*,
Clough, D. (1962). "Need so many babies die?" *Daily Sketch*.
Hughes, P. (1962). "Thousands of babies need not have died." *Daily Mirror*.
Landrith, A. (1962). "Crisis in childbirth!" *Daily Mirror*.
[Anon] (1962). "The dangerous day in human life." *Lincolnshire Echo*.
Clippings from Pp/nbt/m/11/1: Publicity folder including press releases and press clipping,

asphyxia and the idea that babies were dying unnecessarily created a scandal in the press in 1962, which in turn had an impact on medical research.

It was not only the public outcry about deaths due to birth asphyxia which influenced clinicians. The Survey team which directly informed the medical professions of their findings. Butler was interviewed by leading medical journals and published short articles in the *BMJ* and *Lancet,* and the report was reviewed in various international medical journals including the *American Journal of Obstetrics and Gynaecology* and the *Archives of Disease in Childhood*.[490] The Survey team also held several symposia in 1962 and 1963 for the medical community to inform them of their findings, and Butler travelled across Britain giving presentations and lectures to medical societies.[491]

A short report of one of the symposia held at the Royal College of Obstetricians and Gynaecologists in November 1962 was published in the *Lancet*.[492] Professor Nixon, UCH, who had initiated the Survey proclaimed that ‘Perinatal mortality is now one of the most pressing problems of our time … It accounts for as many deaths as the whole of the next 40 years of life.’[493] He further warned the gathered clinicians that:

> Compared with many other countries, the position in England and Wales gives us no cause for pride. Scotland is still lower on the list. The degree of civilisation of a community is directly related to the care it bestows on maternity. Only the very best is good enough for the future mother and her baby; yet in Britain there are many expectant mothers who have only the second best.[494]

1957-58. *National Birthday Trust Archives [PP/NBT]. Archives and Manuscripts, Wellcome Library.* London

490 Pp/nbt/m/11/4: Reviews of the 1963 perinatal mortality survey report, 1963-1965. *National Birthday Trust Archives [PP/NBT]. Archives and Manuscripts, Wellcome Library.* London.

491 Pp/nbt/m/11/7/5: Details of lectures and symposia given to the medical community by the perinatal mortality survey team, 1962-1963. *National Birthday Trust Archives [PP/NBT]. Archives and Manuscripts, Wellcome Library.* London.

492 [Anon] (1962). "Perinatal mortality." *Lancet* **2**: 1164.

493 Ibid.

494 Ibid.

The Director of the survey, Neville Butler, also commented that the analysis had shown that only 1 in 1000 babies was given intratracheal oxygen when undergoing resuscitation, whereas 10 in 1000 were treated with intragastric oxygen. He was concerned that the 1958 figures still represented the situation in 1962 with the reluctant use of what he considered effective treatments, and the continued use of less effective methods, such as intragastric oxygen.[495]

Asphyxia, along with disorders of birth weight, immaturity, and congenital malformations, was described as one of the leading causes of perinatal deaths. The Survey and its resulting publicity not only focused medical attention onto the newborn, but also highlighted the problem of the asphyxiated newborn and the premature infant in the early 1960s in Britain. British clinicians were effectively being accused of failing to provide optimum care to these babies, and therefore of being responsible for unnecessary deaths. These accusations generated a huge push towards improving the care of the asphyxiated and premature infant and boosted neonatal research both in the clinic and in the physiology laboratory.

The fact that the Survey also highlighted deaths due to prematurity was significant. The growing concerns for the care of the newborn, including a growing realisation of the need to address and provide specific care for the premature infant, led many investigators to become increasingly interested in prematurity. As has already been mentioned in earlier chapters, this growing concern for premature infants can be evidenced in the early premature baby units and nurseries set up in the interwar years. After the war the wider context of concerns over improved newborn care included specific research on prematurity. An example of this concern can be found in the 1961 *Report of the Sub-committee on the Prevention of Prematurity and the Care of Premature Infants* of the Ministry of Health Central Health Services Council.[496] The report presented recommendations for a nationwide service for addressing the problem of premature births, including the prevention of such births, the provision of special care baby facilities, transport of premature infants and follow-up schemes. This report and subsequent Ministry of Health

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Ibid.
Intragastric oxygen involved supplying oxygen to the asphyxiated newborn via an intragastric tube. It was believed that oxygen could be absorbed through the gut. The rise to popularity of this technique will be described in detail in chapter 6.

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[Anon] (1961). *Report of the sub-committee on the prevention of prematurity and the care of premature infants. Ministry of health central health services council.* London, HMSO.

Reports throughout the 1960s and 1970s contributed to the establishment of a comprehensive service for premature infants and the growth of the sub-specialty of neonatology in Britain.

It was not only the British who had begun to appreciate the scale of the unnecessary death of babies due to birth asphyxia from the mid-1950s. In New York the Special Committee on Infant Mortality of the Medical Society of the County of New York became aware of the great disparity in how individual clinicians resuscitated the newborn infant. They set about reviewing the problem in the hope of coming to some consensus, publishing a report in 1956.[497] The Committee included many leading clinicians interested in the care of the newborn at the time in New York, including Professor Virginia Apgar, Professor Harold Abramson and William Silverman. The Committee expressed concerns over the lack of consistency in treatment and called for better links between basic scientists and clinicians, as well as improved training and education of medical students on the subject. They reviewed all known methods of resuscitation in use and related the evaluation of each to the then physiological understanding of birth asphyxia and newborn respiration. They concluded that positive pressure methods were most effective, suggesting that for mild asphyxia the airway should be cleared by suction and then an oropharyngeal airway inserted before applying intermittent positive pressure using a face mask and reservoir bag. If the child remains flaccid, then the trachea should be inspected and cleared, and the infant should be intubated with an endotracheal tube and intermittent positive pressure re-applied using a reservoir bag. The Committee did not recommend any of the positive pressure machines then available, but did present a thorough evaluation of each, concluding that the use of a machine was at the discretion of individual hospitals or clinicians. The report went further by recommending possible areas of future research, both physiological and clinical, which were necessary to fill the large gaps in knowledge. Due to the fragmentary knowledge then available the Committee felt that they could offer no definite conclusions on newborn resuscitation.

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497 [Anon] (1956). “Resuscitation of newborn infants. A report by the Special Committee on Infant Mortality of the Medical Society of the County of New York.” *Obstetrics and Gynecology* **8** (3):336-363.

This preliminary report was followed up by a textbook *Resuscitation of the Newborn Infant*, edited by Professor Harold Abramson in 1960, which had an accompanying film for educational purposes.[498] What is evident in the Committee's Report is the emerging consensus amongst an elite group of the east coast clinicians interested in the newborn. Not only were they beginning to agree on protocols for treating the asphyxiated newborn, but there was also a general acceptance of the importance of collaboration, between different medical specialties, and also between basic scientists and clinicians, which will be explored below. Neonatal physiologists, especially, were beginning to be accepted as having a central role in discussions over newborn resuscitation, and just as the basic scientists were stepping into the clinic, clinicians were also stepping in to the laboratory. This theme will be discussed later in this chapter when the growing British and American networks of clinicians and scientists concerned with the newborn are outlined.

Neonatal physiology after World War II

Continuity with the interwar years was not just restricted to clinical research and practice. A new generation of postwar physiologists also maintained an interest in the neonate. Sir Joseph Barcroft undoubtedly had a major impact on the growth of fetal and neonatal physiology in the UK long after his death in 1947. In Cambridge the newly appointed Professor of Experimental Medicine, Robert McCance (1898-1993) shared Barcroft's interest in fetal and neonatal physiology, although he had a specific focus on nutrition. McCance and his colleague Elsie Widdowson (1906-2000) would go on to make some major contributions to the understanding of infant nutrition during the 1950s and the remainder of their careers.[499] More specifically, for the history of newborn resuscitation, Barcroft also influenced the research of the British physiologists Geoffrey Dawes (1918-1996) and Kenneth

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(1958). Committee on infant mortality from 1958-1964. Proposal for a motion picture 'the resuscitation of the newborn infant'. *Archives of the New York Academy of Medicine, New York*, Abramson, H. (1960). *Resuscitation of the newborn infant: Principles and practice*. St Louis, The CV Mosby Company.

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Ashwell, M. (Ed.) (1993). *McCance and Widdowson: A scientific partnership of 60 years, 1933-1993.* London, British Nutrition Foundation.
Widdowson, E. (1995). "Robert Alexander McCance". *Biographical Memoirs of Fellows of the Royal Society* **41**: 263-280.
Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust.

Cross (1916-1990), who emerged as international experts in neonatal physiology, specifically respiratory physiology, during the 1950s and 1960s.

Geoffrey Dawes had trained in physiology and medicine at Oxford University prior to the Second World War. He qualified in 1943, and spent a year as a house clinician at the Radcliffe Infirmary before joining the Laboratory of Pharmacology in 1944.[500] Whilst there he worked on war-related topics such as gas gangrene and nerve gas exposure.[501] After the war he was elected a Fellow and Tutor in physiology at Worcester College and was awarded the Rockefeller Travelling Fellowship which allowed him to spend a year in Harvard at the Department of Pharmacology.[502] On his return to Oxford in 1947 he was given a Royal Society Foulerton Research Fellowship, and in 1948 was appointed the Director of the Nuffield Institute of Medical Research.[503] By any standards this was an accelerated career progression as he was only 30 years old when he became Director.

Dawes' early research interests were concerned with pharmacology and cardio-physiology. However in 1950 he began to shift his focus to fetal physiology. The Nuffield Institute had briefly housed Sir Joseph Barcroft's research team from 1937 to1940, when Barcroft had been using cine-radiography to study fetal circulation.[504] In 1950 Dr Sam Reynolds, an American physiologist from Washington, approached Dawes to conduct some research at the Nuffield Institute, which still housed Barcroft's apparatus and still employed his former technician.[505] Reynolds

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500 Redman, C. (2004). "Dawes, Geoffrey Sharman (1918-1996)." *Oxford Dictionary of National Biography*, Oxford University Press. http://oxforddnb.com/view/article/62623

501 Ibid.

502 Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust.p5.
Redman, C. (2004). "Dawes, Geoffrey Sharman (1918-1996)." *Oxford Dictionary of National Biography*, Oxford University Press. http://oxforddnb.com/view/article/62623

503 Redman, C. (2004). "Dawes, Geoffrey Sharman (1918-1996)." *Oxford Dictionary of National Biography*, Oxford University Press. http://oxforddnb.com/view/article/62623

504 Liggins, G. (1998). "Geoffrey Sharman Dawes CBE." *Biographical Memoirs of Fellows of the Royal Society* **44**: 110-125.

505 Liggins, G. (1998). "Geoffrey Sharman Dawes CBE." *Biographical Memoirs of Fellows of the Royal Society* **44**: 110-125. p116.

wished to study the return of the blood to the placenta and this request prompted Dawes to familiarise himself with Barcroft's publications. Dawes soon realised that 'the physical factors determining the change in the circulation at birth had not been examined. No measurements had been made of changes in pressure or blood flow and a large field of investigation became apparent.'[506] This research whetted Dawes' appetite for fetal physiology and from then on the Institute was almost exclusively devoted to research on the fetus and newborn.

Kenneth Cross qualified in medicine in 1940 at St Mary's Hospital Medical School, London, but soon became interested in physiology.[507] He joined Professor Arthur St George Huggett's (1897-1968) Physiology Department at St Mary's.[508] Huggett, a contemporary and colleague of Barcroft's, had also developed an interest in fetal physiology during the interwar years, and so Cross joined Huggett's fetal research team after the war.[509] Cross developed a particular interest in fetal and neonatal respiration, and throughout the 1950s he conducted clinical studies of newborn respiration. Before moving on it is important to gain an appreciation of the research undertaken by both Cross and Dawes during the 1950s, as it highlights how they came to be regarded as international leaders in neonatal respiratory physiology, and also illustrates the changes in neonatal respiratory physiology after the war.

Again there is a lack of historical literature on mid-twentieth century medicine. The limited writings available do not discuss the role of physiologists and a continued role for experimental physiology during the 1950s and 1960s. Instead these writings tend to focus on the rapid expansion of clinical research during this period.[510] The absence of experimental physiology and animal models in the

506 Ibid. p117.

507 Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust p5-6.

508 Davis, J. (1994). "Kenneth William Cross". *Munks Roll* **9**: 107-109.

509 Brambell, F. (1970). "Arthur St George Joseph Mc Carthy Hugget. 1897-1968." *Biographical Memoirs of Fellows of the Royal Society* **16**: 343-364.
Davis, J. (1994). "Kenneth William Cross". *Munks Roll* **9**: 107-109.

510 Booth, C. (1985). "Medical science and technology at the Royal Postgraduate Medical School: The first 50 years". *BMJ* **291**: 1771-1779.
McGehee Harvey, A. (1981). *Science at the Bedside. Clinical research in American medicine*

literature could be reflective of a general move away from this type of research after the war, which would suggest that the continued reliance of clinicans on animal research and the presence of physiologists in clinical debates surrounding newborn resuscitation, which will be described in the following chapters, was unusual for this period.

Geoffrey Dawes (1918-1996)

In 1952 Dawes and his colleagues published their early research on the effect of ventilation on the pulmonary circulation of the fetus.[511] Like Barcroft they had used preparations of sheep. Having studied Barcroft's research in detail Dawes had realised that it was mainly qualitative, and therefore he wanted to quantify some of the physiological changes which happened during fetal and neonatal life. He hypothesized that since the fetal blood flowed from the arterial trunk to the aorta via the ductus arteriosus, it was reasonable to assume that the pressure in the pulmonary trunk was greater than in the descending aorta.[512] However the reverse was true in adults. Dawes therefore argued that the change must occur at birth or shortly afterwards.[513] Recognizing the lack of quantitative data on pulmonary and aortic pressures at this time and their relation to the start of respiration, the tying of the umbilical cord and the closure of the ductus arteriosus, Dawes and his team set about gathering the data.

They found that on artificial ventilation of the fetal lungs by positive pressure there was 'an immediate fall in pulmonary arterial pressure accompanied by a great

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1905-1945. Baltimore &London, Johns Hopkins University Press.
Reynolds, L. and E.M. Tansey. (Eds.) (2000). *Clinical Research in Britain, 1950-1980*. London, Wellcome Trust.
Booth, C. (1987). "Clinical reearch and the MRC" in *Doctors in science and society. Essays of a clinical scientist*. Cambridge, Cambridge University Press: 238-262.
Booth, C. (2003). "From art to science: The story of clinical research". In *A Physician Reflects: Herman Boerhaave & other essays*. London, Wellcome Trust Centre for the History of Medicine.

511 Ardan, G., G. Dawes, et al. (1952). "The effect of ventilation of the foetal lungs upon the pulmonary circulation." *Journal of physiology* **118**: 12-22.

512 Ibid. p12.

513 Ibid. p12.

increase in the velocity of blood flow through the lungs'.[514] They concluded from their observations that:

> The changes in pulmonary arterial pressure and circulation time … [were] primarily due to aeration of the lungs. Whether these changes … [were] themselves in any way responsible for the closure of the ductus arteriosus remain[ed] to be seen.[515]

It was this final point which directed the team's research over the following years, as they began to investigate the closure of the ductus arteriosus.

Another significant aspect of this paper was the description of the technique which had allowed them to maintain and study the fetal lamb, with its chest opened and with pressure records of the great vessels, for long enough to watch closure of the ductus arteriosus.[516] Dawes had used Barcroft's original technique and had continued to improve on it, so that his experimental models remained as close to the 'normal' state as possible.

Barcroft had used an 'acute' preparation of fetal sheep in his investigations on fetal physiology.[517] The pregnant ewe was anaesthetised and placed in a warm saline bath. The uterus was then opened by caesarean section to expose the fetus. The fetus was removed from the uterus but remained under the heated saline attached to the placenta via the umbilical cord. Unlike in other mammals, the sheep placenta did not begin to separate which meant that the investigator could effectively work with an exteriorised fetal lamb preparation.

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514 Ibid. p19.

515 Ibid. p21.

516 Ibid. p21.

517 Mason, M., J. Kennedy, et al. (1938). "Direct determination of foetal oxygen consumption." *Journal of Physiology* **93**: 21-22.
Barcroft's technique had equally been based on earlier work by Arthur St George Hugget: Hugget, A. S. G. (1927). "Foetal blood-gas tensions and gas transfusion through the placenta of the goat." *Journal of Physiology* **62**: 373-384.

Following on from their 1952 paper Dawes' research team published another paper in 1953 which considered the changes in newborn lungs at birth.[518] Their research had been concerned with the increased pulmonary blood flow at birth, linked to the ventilation of the newborn lungs. 'These experiments led to the conclusion that ventilation of the lungs for the first time after birth leads to a decrease of pulmonary vascular resistance.'[519]

The Nuffield research group continued to gather and publish quantitative data on blood pressures and volumes through the principal vessels and organs in the fetus and newborn. In 1954 they published their calculations of the volume of blood flow in all the principal vessels as a percentage of the cardiac output.[520] They found that with lung expansion there was a three- to ten-fold increase in blood flow through the left pulmonary artery.[521] However, they concluded that:

> Although rupture of the umbilical cord is an abrupt event, the expansion of the lungs and closure of the ductus arteriosus takes several hours. There is therefore an intermediate condition of the circulation, between that in the foetus and that in the adult.[522]

They explained this neonatal state in a later paper in more detail.

Contrary to Barcroft, who thought the ductus arteriosus closed shortly after birth, the Nuffield group had found that in some newborns it remained patent for a longer time. Dawes's group were intrigued and began to investigate the effect this prolonged patency might have. By 1955 they had shown that a patent ductus arteriosus in the newborn could actually help to relieve cyanosis caused by intrapulmonary arterio-venous shunts.[523] If blood was passing through poorly

518 Dawes, G., J. Mott, et al. (1953). "Changes in the lungs of the new-born lamb." *Journal of Physiology* **121**: 141-162.

519 Ibid. p141.

520 Dawes, G., J. Mott, et al. (1954). "The foetal circulation in the lamb." *Journal of Physiology* **126**: 563-587.

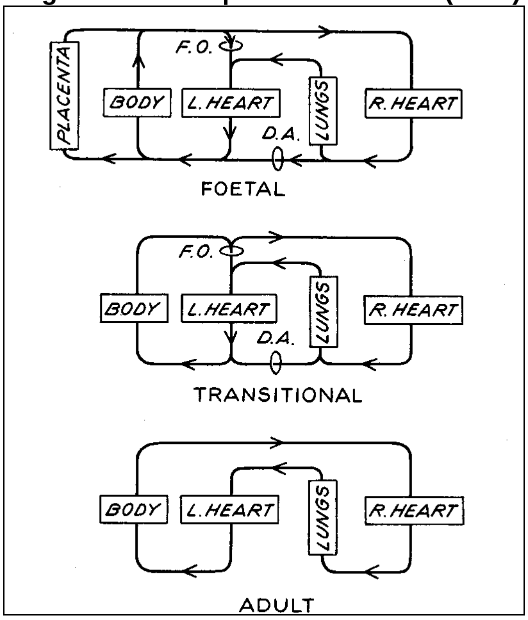
521 Ibid. p586.

522 Ibid. p586.

523 Born, G., G. Dawes, et al. (1955). "The relief of central cyanosis caused by pulmonary arterio-venous shunts by constriction of an arterial ductus arteriosus." *Journal of Physiology* **130**: 167-190.

expanded areas of lung and was therefore poorly oxygenated, the ductus arteriosus would allow this blood to re-circulate through the lungs and therefore absorb more oxygen.[524] They therefore showed that a phenomenon, which had been considered a disturbance of the normal mechanism, was in fact a beneficial adaptation of the newborn to unfavourable conditions. This ability of the newborn to exist in a temporary transitional phase (illustrated in figure 7), when experiencing a short period of asphyxia, allowed it to make maximum benefit of both 'adult' and 'fetal' circulation, and again illustrated the uniqueness of this phase of life .

Figure 13. Diagrammatic explanation of the changes in respiratory circulation between the fetus and adult, illustrating the transitional neonatal stage described by Dawes. The diagrams are adapted from Dawes (1968) Foetal and Neonatal Physiology



During the late 1950s Dawes' research group had turned their interests towards fetal cardiovascular and metabolic responses to asphyxia. Initially the team examined the oxygen consumption of the normal fetal sheep and its cardiovascular response to oxygen deprivation. Partly inspired by Cross's research on human newborns, Dawes began to study the relationship between oxygen consumption and arterial oxygen saturation in the fetus and newborn.[525] Cross had demonstrated that the oxygen consumption of the newborn fell when it

524 Ibid.

525 Acheson, G., G. Dawes, et al. (1957). "Oxygen consumption and the arterial oxygen saturation in foetal and new-born lambs." *Journal of Physiology* **135**: 623-642.

breathed gas mixtures with low oxygen content.[526] Dawes and his colleagues found similar results in the newborn lamb.[527] The work on lambs also showed that the rate of oxygen consumption per kilogram of body weight did not alter during the final few weeks of gestation, mainly due to increased umbilical blood flow. Dawes *et al* argued that ‘the oxygen tension of the arterial blood may be one of the principal determinants of umbilical flow towards the end of gestation’.[528]

Concerned at the lack of experimental evidence, regarding the functional efficiency of chemoreceptor reflexes at birth, the Oxford team set about examining these reflexes in rabbits.[529] There was general disagreement in the literature as to whether or not the aortic and carotid bodies functioned at birth. Cross and Oppé believed they were active, whereas Miller and Smull argued the opposite.[530] After their research on newborn rabbits, Dawes *et al* were in agreement with Cross and Oppé and argued that they had demonstrated the activity of the carotid body at birth.

The Nuffield group were also intrigued by the tolerance of newborn mammals to anoxia, and towards the end of the 1950s they conducted research on various species of animals comparing the reactions of newborns and adults to anoxia.[531] By 1959 they had demonstrated that this unique tolerance of the newborn mammal was due to its ability to maintain circulation during anoxia.[532] The ability to

526 Cross, K., J. Tizard, et al. (1955). "The metabolism of new-born infants breathing 15% oxygen." *Journal of Physiology* **129**: 69-70.

527 Acheson, G., G. Dawes, et al. (1957). "Oxygen consumption and the arterial oxygen saturation in foetal and new-born lambs." *Journal of Physiology* **135**: 623-642.

528 Ibid. p640.

529 Dawes, G. and J. Mott (1959). "Reflex respiratory activity in the new-born rabbit." *Journal of Physiology* **145**: 85-97.

530 Cross, K. and T. Oppé (1952). "The effect of inhalation of high and low concentrations of oxygen on the respiration of the premature infant." *Journal of Physiology* **117**: 258-291, Miller, H. and N. Smull (1955). "Further studies on the effects of hypoxia on the respiration of newborn infants." *Pediatrics* **16**: 93-103.

531 Dawes, G., J. Mott, et al. (1959). "The importance of cardiac glycogen for the maintenance of life in foetal lambs and new-born animals during anoxia." *Journal of Physiology* **146**: 516-538.

532 Ibid.

maintain circulation was shown to be linked to high carbohydrate stores in the heart which could be anaerobically metabolised.

Kenneth Cross (1916-1990)

As has already been mentioned, Cross had joined Huggett's physiology department, and developed an early interest in neonatal physiology, particularly respiration. From 1949 to 1952 Cross had been studying respiration in premature infants. He had been working with the paediatrician Thomas Oppé to measure the respiratory rate and volume of the premature infant.[533] He found a positive correlation between weight and average minute volume, with an average respiration rate of 34-39 per minute.[534] Cross had developed a plethysmograph which allowed him to measure the respiratory movements of healthy infants. Throughout the early 1950s he was continuing, as Barcroft had before him, to establish the normal physiology of the newborn.

In 1951 Cross published a paper 'The effect of inhalation of high and low oxygen concentrations on the respiration of the newborn infant', which continued on the research of interwar clinicians and scientists, such as Eastman and Barcroft.[535] He was particularly interested in how the respiratory reflexes developed in the newborn. Using the plethysmograph he had found that the carotid body chemoreceptors were active in the newborn, and therefore the newborn could respond to reduced oxygen concentrations.[536] However, he demonstrated that the newborn failed to maintain the increased minute volume of respiration in response to reduced oxygen. Cross hypothesised that mild anoxia may cause medullary depression.[537] The results of a further experiment, in which an attempt was made

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533 Cross, K. and T. Oppé (1952). "The respiratory rate and volume in the premature infant." *Journal of Physiology* **116**: 168-174.

534 Ibid.

535 Cross, K. and P. Warner (1951). "The effect of inhalation of high and low oxygen concentrations on the respiration of the newborn infant." *Journal of Physiology* **114**: 283-295.

536 Ibid.

537 Cross, K., J. Hooper, et al. (1954). "Anoxic depression of the medulla in the new-born infant." *Journal of Physiology* **125**: 628-640.

to stimulate the medulla when the infant was hypoxic using carbon dioxide, supported this hypothesis.[538]

Having investigated the response of the newborn to oxygen, Cross became concerned by the lack of agreement on the effect of carbon dioxide on the newborn. In 1953 he published his results of research on premature infants, which showed that the infants had a 'significant response' to carbon dioxide and that this response was more pronounced than in adults.[539] They therefore concluded that the newborn's respiratory centre was more sensitive to carbon dioxide than the adult's.[540]

Realising the significance of their research, and that of other fetal and neonatal physiologists to clinicians, Cross and his colleagues published an article in the *American Journal of Obstetrics and Gynecology* in 1954. The article summarised the then current physiological understanding of the role of hypoxia in fetal and neonatal life.[541] The paper described the factors involved in the onset of pulmonary respiration in the newborn, the adaptations made by fetal haemoglobin, and stressed that the factors which induced pulmonary respiration were still not fully understood. They explained that there were only two lines of investigation available. Researchers could either examine fetal respiration *in utero* or study the control of respiration in the newborn once it had been established. They emphasised that it had to be appreciated that there were 'essential differences between these two stages' and they were 'examining a continuous yet slowly changing system'.[542] The newborn differed from both the adult and fetus, showing 'respiratory irregularity' which resembled the fetus, and also a greater response to carbon dioxide than the adult, which was the complete opposite to the fetal

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538 Ibid.

539 Cross, K., J. Hooper, et al. (1953). "The effect of inhalation of carbon dioxide in air on the respiration of the full-term and premature infant." *Journal of Physiology* **122**: 264-273.

540 Ibid.

541 Cross, K., E. Killick, et al. (1954). "Hypoxia in fetal and neonatal life." *American Journal of Obstetrics and Gynecology* **68**(1): 81-90.

542 Ibid. p82.

response.[543] Although the newborn did exhibit an increase in respiratory minute volume with decreased oxygen, this response was short-lived. It appeared that the infant's respiratory centre was quickly depressed by falls in oxygen.[544]

Cross *et al* argued that the sensory stimuli undoubtedly played a role in the onset of respiration at birth, although this was still not fully understood.[545] The main vascular changes involved an increase in blood through the pulmonary arteries as well as a fall in umbilical pressure. Geoffrey Dawes had shown that the increase in pulmonary blood flow occurred after lung inflation and ventilation, so it was unlikely this played a role in the onset of respiration. The fall in umbilical pressure tended to precede the onset of respiration, so it was possible that this played a stimulatory role. However, Cross *et al* argued that:

> It seems most probable, from present knowledge, that the stimulus of oxygen lack is responsible for the onset of respiration. It should be recognized that it has to be explained why the progressive hypoxia of late prenatal life does not cause more marked intrauterine breathing and also how it is that a medulla, which is easily depressed by low oxygen in immediate postnatal life, can be stimulated by a further fall in oxygen tension when the emergency of birth occurs.[546]

They then described the work of Eastman and Barcroft which had examined the unique characteristics of fetal haemoglobin and also discussed the tolerance of both the fetus and newborn to anoxia. Cross and his colleagues concluded that hypoxia played a role in the formation of fetal haemoglobin and also newborn respiration and therefore it should not be considered 'an incidental factor but a necessity of fetal life and an important influence in neonatal life'.[547]

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543 Ibid. p83.

544 Ibid. p83.

545 Ibid. p84.

546 Ibid. p84-85.

547 Ibid. p89.

As was mentioned in the previous chapter, Cross has a specific interest in asphyxia neonatorum.[548] By the late 1950s Cross had begun to collaborate with Dawes. Clearly both could see the benefits of such a partnership, as Cross had access to ample newborn babies for clinical studies, whereas Dawes had a steady supply of pregnant sheep for physiology experiments. They studied the effect of anoxia on the oxygen consumption and cardiac output in sheep.[549] They were particularly interested in whether the oxygen consumption of newborns fell during anoxia, a response which was apparently not seen in adult animals.[550] The pair began a long collaboration researching asphyxia neonatorum, which became increasingly clinical in nature throughout the 1960s.

Having turned his mind towards the human newborn by the end of the decade, Dawes had realised that lambs were no longer the most suitable research subjects. He came to the conclusion that higher primates would be the most appropriate animal models for such comparative research.[551] However, lambs were still the best available animal models in Oxford. It was therefore good fortune that, in 1959, he was offered the opportunity to join Professor William Windle in Puerto Rico to study asphyxia in rhesus monkeys. This research and the research he continued to conduct at the Nuffield Institute contributed to massive advances in neonatal physiology during the 1960s, with a particular impact on newborn resuscitation, which will be considered in more detail in later chapters.

Despite the death of Bacroft in 1947, his research on the neonate continued after the war. Cross and Dawes emerged as international leaders on fetal and neonatal respiratory physiology during the 1950s. Like Barcroft before them they appreciated the clinical significance of their research. Changes in medical research during the interwar years, which have been discussed, made it easier for these post-war physiologists to contribute to the clinical sphere during the 1950s

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548 As mentioned in Chapter 4 Cross had developed a device for newborn resuscitation, the electrophrenic stimulator, during the late 1940s.

549 Cross, K., G. Dawes, et al. (1959). "Anoxia, oxygen consumption and cardiac output in new-born lambs and adult sheep." *Journal of Physiology* **146**: 316-343.

550 Ibid.

551 Liggins, G. (1998). "Geoffrey sharman dawes.C.B.E." *Biographical Memoirs of Fellows of the Royal Society* **44**: 110-125.

and 1960s. The impact of the research of Cross and Dawes and their interactions with clinicians will be discussed in the remainder of the thesis.

Equally, just as Cross and Dawes were becoming increasingly aware of the clinical relevance of their research towards the end of the 1950s, the importance of fetal and neonatal physiological research to neonatal medicine was also becoming apparent to clinicians. This growing appreciation culminated in a special meeting held at the annual conference of the British Paediatric Association (which later became the Royal College of Paediatrics and Child Health), at Scarborough in 1959, where Dawes had been invited to give the Still Memorial Lecture.[552] The details and significance of this meeting will become more apparent in the following section. However it is important to realise that there was a gradual change in attitudes during the 1950s as both clinicians and physiologists began to realise the need for collaboration. The 1950s witnessed the formation of an important network of individuals who shared an interest in the physiology and care of the newborn, which will be mapped below.

The neonatal network and the birth of neonatology

'Neonatology' and 'neonatologist' were first coined by the American paediatrician AJ Schaffer in 1960. Schaffer stated that: 'The one designates the art and science of diagnosis and treatment of disorders of the newborn infant; the other the clinician whose primary concern lies in the specialty.'[553] However this does not mark the conception of the sub-specialty of neonatology in the USA or Britain. As has already been mentioned, towards the end of the 1950s groups of clinicians and physiologists had emerged in both the US and Britain with a shared interest in the neonate. These groups of researchers and individual clinicians had many social links and by the end of the decade had formed a network. This 'neonatal network' became instrumental in directing and deciding newborn care during the 1960s and also in the development of neonatology. This section will now discuss the development of this network during the late 1950s, with a particular focus on Britain and America, drawing on oral histories and the movement of key actors to

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552 McCance, R. Sa/nns/f.3: 'the foundation and early years of the neonatal society'. *The Neonatal Society Archive [SA/NNS]. Archives and Manuscripts, Wellcome Library.* London.

553 Schaffer, A. (1960). *Diseases of the newborn*. Philadelphia & London, WB Saunders Co. p1.

re-construct and map the network. It will also discuss the growing authority of this network in directing the care of the newborn during the 1960s.

My use of the term network has been influenced by the sociological work on 'invisible colleges' by the sociologists of science Diana Crane and Derek J de Solla Price.[554] As Crane argued in the introduction to her book, *Invisible Colleges*, 'the logistic growth of scientific knowledge is the result of the exploitation of intellectual innovations by a particular type of social community'.[555] With this in mind she established the importance of social organization in scientific development.[556] I would argue that the same is true of medical knowledge and practice, and therefore feel justified in applying her theory, of the central importance of social networks and communication, to the growth of scientific knowledge, to the production of medical knowledge and the dissemination of medical practice.

Crane and Price uncovered a number of these invisible colleges amongst scientists, and provided evidence of how they interacted and contributed to the production of scientific knowledge. These interactions involved the sharing of research findings and collaborative work. However, Crane and Price tended to emphasis formal communication channels, such as the production of papers and documents. In a more current analysis of the invisible college, Leah Loevrouw has come up with a more nuanced definition: 'An invisible college is a set of informal communication relations among scientists or other scholars who share a specific common interest or goal.'[557] It is Loevrouw's definition which has provided a framework for my use of the term neonatal network.

This conceptual tool, the neonatal network, will be used to describe the group of actors, both clinicians and scientists, who shared an interest in the fetus and

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554 Price, D. J. D. (1963). *Little science, big science*. New York, Columbia University Press, Crane, D. (1972). *Invisible colleges. Diffusion of knowledge in scientific communities*. Chicago & London, The University of Chicago Press.

555 Crane, D. (1972). *Invisible colleges. Diffusion of knowledge in scientific communities*. Chicago & London, The University of Chicago Press. p2.

556 Ibid. p2.

557 Lievrouw, L. A. (1989). "The invisible college reconsidered. Bibliometrics and the development of scientific communication theory." *Communication Research* **16**(5): 615-628.

neonate, and the informal and formal associations they formed during the 1950s and 1960s. The social interactions between members of the neonatal network, as Crane's invisible colleges have shown, became invaluable in both the production and dissemination of knowledge concerning the asphyxiated newborn. Within the medical sphere, this informal neonatal network gained power and influence over issues of clinical research, care and practice towards the end of the 1960s. Below the formation, growth and mechanics of the neonatal network I have identified will be described.

In America a network of clinicians and physiologists interested in the neonate emerged on the east coast during the 1950s. In New York Virginia Apgar, an obstetrical anaesthetist, had begun to take an interest in the immediate care and resuscitation of the newborn from the early 1950s, and had established a research team at Columbia University.[558] Apgar collaborated with Richard Day, from the State University of New York, who conducted research into lung inflation in newborns during the 1950s.[559] Both Day and Apgar also worked with L Stanley James, who was a researcher in Apgar's department from 1955 to 1959.[560] All three were involved in developing Apgar's scoring system for newborns, and also promoted the use of endotracheal intubation for resuscitation.

Apgar also had a close relationship with researchers at Johns Hopkins University, Baltimore, where she had gained a Masters Degree in Public Health in 1959.[561] Johns Hopkins was home to Nicholson Eastman, who, as described in chapter 2,

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558 Baskett, T. (2000). "The resuscitation greats: Virginia Apgar and the newborn Apgar score." *Resuscitation* **47**:215-217.
Apgar was introduced in Chapter 3. She had developed a scoring system, the Apgar score, for assessing neonates at birth. She was also one of the earliest advocates of intubation and positive pressure ventilation for treating asphyxiated newborns in America.

559 Johnson, L. (1980). "Shared remembrances of Richard L Day". In *Historical review and recent advances in neonatal and perinatal medicine*. G. Smith and D. Vidyasagar (Eds.). Illinois, Mead Johnson Nutrition Division. **Vol 1**: xvi-xviii. Discussion of Day's work on lung expansion in newborns can be found in chapter 3.

560 [Anon] (1995). "L Stanley James, MD". *P&S Journal* **15**(1): http://www.cu,c.columbia.edu/news/journal/journal-o/archives/jour_v15n11_0047.html.

561 Baskett, T. (2000). "The resuscitation greats: Virginia Apgar and the newborn Apgar score." *Resuscitation* **47**:215-217.

conducted pioneering research on fetal and neonatal blood during the 1930s.[562] Eastman was responsible for directing many young obstetricians towards research careers during the 1950s. He had close ties with the physiologist Donald H Barron at Yale, and sent many of his young obstetricians to Yale to receive research training from Barron.[563] Barron had worked with Sir Joseph Barcroft during the interwar years, and contributed to Barcroft's groundbreaking neonatal physiology research.[564]

Barron's physiology research group also trained clinicians from Boston in basic research methods.[565] The Boston paediatricians had been sent to Yale by Clement Smith, Professor of Paediatrics at Harvard, and author of *The Physiology of the Newborn Infant* (1945).[566] He worked at both the Boston Lying-In Hospital and Children's Medical Centre, alongside another leader in newborn care at the time, Charles Davenport Cook, who was head of out-patient services at the Boston Children's Medical Centre.[567] Cook was particularly interested in hyaline membrane disease and the respiratory support of newborns.[568]

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562 Nelson, N. (1980). "Perinatal medicine". in *Historical review and recent advances in neonatal and perinatal medicine.* G. Smith and D. Vidyasagar (Ed.). Illinois, Mead Johnson Nutritional Division. **vol. 1:** 3-8.

563 Ibid. in (Ed.). p6.

564 Franklin, K. (1953). *Joseph Barcroft 1872-1947*. Oxford, Blackwell Scientific Publishing.
Details of Barcroft and Barron's collaborative work can be found in chapter 2.

565 Nelson, N. (1980). "Perinatal medicine". in *Historical review and recent advances in neonatal and perinatal medicine.* G. Smith and D. Vidyasagar (Ed.). Illinois, Mead Johnson Nutritional Division. **vol. 1:** 3-8. p6.
As mentioned in Chapter 2, Smith had been a contemporary of Barcroft, and one of the earliest clinicians to investigate the unique physiology of the fetus and neonate during the interwar years.

566 Nelson, N. (1980). "An appreciation of clement a smith". in *Historical review and recent advances in neonatal and perinatal medicine*. G. Smith and D. Vidyasagar (Ed.). Illinois, Mead Johnson Nutrition Division. **1:** xii-xiii.
Nelson, N. (1980). "Perinatal medicine". in *Historical review and recent advances in neonatal and perinatal medicine.* G. Smith and D. Vidyasagar (Ed.). Illinois, Mead Johnson Nutritional Division. **vol. 1:** 3-8. p6.

567 Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust. p15

568 Ibid. p15-16.

Geographically the Boston institutions were very close together, which encouraged the growth of research networks of individuals interested in the newborn.[569] Clinicians from the Lying-In Hospital and the Children's Medical Centre had a close working relationship, and they were also in close proximity to the Harvard Pulmonary Physiology research group, which facilitated lots of collaborative study.[570] Boston produced some very important neonatal research, including the 1959 discovery of surfactant lack in the lungs of newborns suffering from hyaline membrane disease. The Boston clinicians and researchers also developed research networks with the New Yorkers during the 1950s.[571] These collaborations and interactions proved very fruitful, and had a major impact on the growth of similar networks in Britain.

As has already been mentioned, in Britain after the war several neonatal physiology research groups were established. Robert McCance and Elsie Widdowson carried on the research mantle of Sir Joseph Barcroft, with an emphasis on nutrition, at Cambridge. The physiology department at St Mary's, London, which was run by Professor Arthur Huggett a contemporary of Barcroft, was also home to Kenneth Cross, who had a specific interest in neonatal respiratory physiology. Cross continued this research at the London Hospital as Professor of Physiology from 1960. In Oxford Geoffrey Dawes, Director of the Nuffield Research Unit, also continued Barcroft's research on fetal and neonatal physiology, particularly pulmonary respiratory physiology.

As discussed, the collaborative relationship which developed between Dawes and Cross during the 1950s and 1960s became a key component of the advances made in the understanding and treatment of asphyxia in the newborn. Dawes had the facilities and funding to support the most cutting-edge animal physiology research at the time. Cross, working within a medical school, not only had access to human newborns, but was also key to identifying clinical problems which he felt basic physiological research could solve, and for identifying potentially gifted

569 McAdams, R. (2007). Interview with Dr Herbert Barrie, 31st Jan.

570 Nelson, N. (1980). "Perinatal medicine". in *Historical review and recent advances in neonatal and perinatal medicine.* G. Smith and D. Vidyasagar (Ed.). Illinois, Mead Johnson Nutritional Division. **vol. 1:** 3-8. p7.

571 McAdams, R. (2007). Interview with Dr Herbert Barrie, 31st Jan.
Ibid. in (Ed.).

research-minded clinicians, who he enticed to spend time conducting basic physiology research.[572] The importance of these two figures and their relationship on the development of the neonatal network will be described below. In later chapters their roles in the debates surrounding newborn resuscitation will also become clear.

Unlike Cross, by the late 1950s Dawes had gained an international reputation as a leader in his field. Dawes had close ties with the east coast American researchers, having been awarded a Rockefeller Travelling Fellowship at Harvard after the war.[573] His reputation enticed a number of aspiring American clinicians and scientists to spend time at his Oxford Unit from the 1950s, notably Sam Richmond who had first sparked Dawes' interest in neonatal physiology in 1950.[574]

Dawes' links with American researchers and his standing as an international leader in neonatal physiology was also highlighted by his invitation to join William Windle's research unit in Puerto Rico in 1959.[575] Windle had been awarded funding from the National Institute of Child Health and Development, in the US, to gather 'the best minds in neonatal research' to study the effects of birth asphyxia on the subsequent development of newborns using primates.[576] Dawes and other members of his Unit made four visits to the Puerto Rican laboratory between 1959 and 1966, which led to some fruitful collaborative research between the British and

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572 Hull, D. (2007). Email correspondence "neonatal resuscitation".
McAdams, R. (2007). Interview with Professor Alec Campbell and Professor Mike Tunstall, 27th August.
McAdams, R. (2007). Interview with Professor John A Davis, 5th June.
McAdams, R. (2007). Interview with Dr Edmund Hey and Professor Sam Richmond, 20th November.

573 Redman, C. (2004). "Dawes, Geoffrey Sharman (1918-1996)." *Oxford Dictionary of National Biography*, Oxford University Press. http://oxforddnb.com/view/article/62623
McAdams, R. (2007). Interview with Professor Alec Campbell and Professor Mike Tunstall, 27th August.

574 Liggins, G. (1998). "Geoffrey Sharman Dawes CBE." *Biographical Memoirs of Fellows of the Royal Society* **44**: 110-125.

575 Ibid.

576 Ibid. p121.

Americans.[577] The lab 'served as a training area in perinatal and neonatal care for many young clinicians'.[578]

These trans-Atlantic links were not limited to physiologists. During the 1950s and 1960s there was a tacit understanding that the BTA (Been/beam To America) was an essential component of the training for aspiring paediatricians with an interest in the newborn.[579] After the war a number of travelling research fellowships, similar to the Rockefeller fellowship awarded to Dawes, were available for British clinicians to spend time in US institutions to conduct research or to generally share skills and experience with their American counterparts and vice versa. One such award was the Nuffield Research Fellowship. The British paediatrician Peter Tizard was awarded this fellowship in 1951 and spent a year at the Harvard Medical School working alongside Cook at the Children's Medical Centre, Boston.[580] Tizard's time in Boston helped to cement his interest in the care of premature infants, and on his return he established the Nuffield Neonatal Research Unit at Hammersmith Hospital, which had become a leading research unit by the late 1960s.[581]

Another significant travelling fellowship was the Harvard Research Fellowship, which allowed clinicians to spend a year in Boston conducting basic research. During the late 1950s and early 1960s this fellowship was awarded to a series of clinicians who developed a specific interest in neonatal medicine and research, and was organized through a 'sort of old boys' network', with each fellow

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577 Ibid.
McAdams, R. (2007). Interview with Professor Forrester Cockburn, 26th March.

578 Goldstein, P. (1980). "Birth asphyxia". in *Historical review and recent advances in neonatal and perinatal medicine*. G. Smith and D. Vidyasagar (Ed.). Illinois, Mead Johnson Nutritional Division. **vol.1:** 177-184. p182.

579 McAdams, R. (2007). Interview with Dr Edmund Hey and Professor Sam Richmond, 20th November.
McAdams, R. (2007). Interview with Professor John Forfar, 19th June.

580 Meadows, R. (2004). "Tizard, Sir (John) Peter Mills (1916-1993)." *Oxford Dictionary of National Biography*, Oxford University Press. http://www.oxforddnb.com/view/article/53373.

581 Davis, J. (1996). "Tizard, Sir (John) Peter Mills". *Munks Roll* 9:518-520.

subsequently nominating his successor. [582] Thomas Oppé, a paediatrician at Great Ormond Street Hospital, was awarded the fellowship in 1957, and spent a year working alongside Professor Clement Smith which had fostered his interest in the neonate.[583] Oppé went on to become the Professor of Paediatrics at St Mary's Hospital Medical School, London, and continued his interest in the care of the newborn and premature infants throughout his career.[584] On his return Oppé had recommended his colleague at Great Ormond Street, Herbert Barrie, for the fellowship.[585]

Barrie travelled to Boston in 1958 and spent a year working alongside Cook on the pulmonary physiology of the newborn. Barrie describes a stimulating collaborative research environment in Boston at the time, with close links between Cook's department and that of Apgar in New York.[586] It was during his time in Boston that Barrie developed a particular interest in newborn resuscitation and pulmonary physiology. Influenced greatly by Apgar's use of endotracheal intubation on the asphyxiated newborn, Barrie became the major British advocate for this technique on his return.[587] The role of Barrie in the debates surrounding newborn resuscitation during the 1960s will become apparent in the following chapters.

Barrie was followed by Leonard Birnie Strang, who also spent a year working with Cook at the Children's Medical Centre, studying the pulmonary vasculature of the newborn.[588] Strang eventually became Professor of Paediatrics at University College Hospital (UCH), London, where he established his world renowned research group who looked at the physiological changes of the newborn lungs at birth. Strang was followed to Boston by Osmond Reynolds in 1962-1963, who

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582 McAdams, R. (2007). Interview with Dr Herbert Barrie, 31st Jan

583 Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust.p6.

584 Richmond, C. (2007). "Obituary. Professor Thomas Oppe." *The Independent*.

585 McAdams, R. (2007). Interview with Dr Herbert Barrie, 31st Jan

586 Ibid.
Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust p18-19.

587 McAdams, R. (2007). Interview with Dr Herbert Barrie, 31st Jan

would eventually head up Strang's neonatal research group at UCH.[589] The UCH group 'became a dominant force in British academic paediatrics' during the 1960s and 1970s, with both Strang and Reynolds making major contributions to ventilatory support of newborns and our understanding of lung development in the fetus and newborn.[590]

Besides the two large neonatal clinical research units at UCH and Hammersmith, headed by Strang and Tizard respectively, there were a number of smaller research groups and individuals scattered across the UK.[591] Some of the notable smaller units included Barrie at St Thomas' and later at Charing Cross, and a small group in Aberdeen and Dundee, which included the obstetricians Sir Dugald Baird, James Walker, Ross Mitchell and the anaesthetist Mike Tunstall.[592]

Both the physiology research units and the academic paediatric units acted as training grounds for many of the young paediatricians who would go on to become leading neonatologists during the 1970s and 1980s. Important collaborative relationships between clinicians and physiologists were also facilitated. Examples include Tizard, who not only spent time in Boston, but also developed a close relationship with Dawes in Oxford, spending a sabbatical year working at the Nuffield Unit and eventually relocating to Oxford in 1972.[593] Tizard's unit was viewed by 'ambitious paediatricians… as the place to work in order to learn

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588 Davis, J. (2000). "Leornard Birnie Strang." *Munks Roll* **10**: 472-474.

589 Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust p14.

590 Davis, J. (2000). "Leornard Birnie Strang." *Munks Roll* **10**: 472-474.

591 Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust p16.
McAdams, R. (2007). Interview with Dr Herbert Barrie, 31st January.
McAdams, R. (2007). Interview with Professor John A Davis, 5th June.
McAdams, R. (2007). Interview with Professor Forrester Cockburn, 26th March.
Hull, D. (2007). Email correspondence 'neonatal resuscitation'.

592 Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust p12-13.
McAdams, R. (2007). Interview with Professor Alec Campbell and Mike Tunstall, 27th August.

593 Davis, J. (1996). "Tizard, Sir (John) Peter Mills". *Munks Roll* 9:518-520.

intensive care of the newborn', and he is said to have 'trained a generation of paediatricians who were to head academic departments in Britain and abroad'.[594]

Dawes' Nuffield Unit also trained young clinicians interested in newborn physiology, providing one year fellowships, which came to be regarded as just as essential training components for young neonatologists as the BTA.[595] John Davis, having met Kenneth Cross at St Mary's Hospital, had developed an interest in newborn resuscitation and was advised to spend a year working with Dawes in Oxford, receiving the first research fellowship.[596] Davis had also been awarded one of the Harvard Research Fellowships during the early 1950s, and had worked with Clement Smith.[597] Davis stayed in Oxford for a year and then joined Tizard at the Hammersmith to continue his clinical research until he became Professor of Paediatrics in Manchester in 1967.[598]

Other paediatricians were awarded the Nuffield research fellowship to work at Dawes' unit and included Forrester Cockburn, who worked there in 1965-66.[599] Cockburn joined Dawes on his research trip to Puerto Rico to study the effect of birth asphyxia on newborn development in primates. Cockburn later moved back to Edinburgh and then Glasgow, and became a vocal advocate of endotracheal intubation for newborn resuscitation in Scotland.[600] Other significant holders of the Nuffield research fellowship include Sir David Hull, who helped to demonstrate the importance of brown adipose tissue in the temperature regulation of newborns, and also Alec Campbell, who contributed to the debates surrounding newborn resuscitation during the 1960s. All of whom came to head university departments of child health; in Glasgow, Sheffield and Aberdeen respectively.

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594 Robinson, R. (1993). "Obituary: Sir Peter Tizard." *BMJ* **307**:1207.

595 McAdams, R. (2007). Interview with Dr Edmund Hey and Professor Sam Richmond, 20th November .
McAdams, R. (2007). Interview with Professor Forrester Cockburn, 26th March.

596 McAdams, R. (2007). Interview with Professor John A Davis, 5th June.

597 Ibid.

598 Ibid.

599 McAdams, R. (2007). Interview with Professor Forrester Cockburn, 26th March.

600 Ibid.

Kenneth Cross possibly played a more significant role in the growth of these relationships between aspiring clinicians and physiologists. As a Professor of Physiology in a large medical school he was responsible for the training of undergraduate medical students in physiology and had close ties with qualified doctors working within the medical school and its hospitals. In contrast Dawes' Unit had no links with the hospitals in Oxford. It was Cross who interacted with clinicians, identified those with potentially fruitful research careers, helping to direct them in their research, providing necessary advice and skills, and, in a lot of cases, sending them to Dawes' Oxford Unit for more specialist facilities.[601]

The Neonatal Society

One of the most important and visible incarnations of the neonatal network established in Britain was the Neonatal Society which was conceived on 24th April 1959 at a meeting of the British Paediatric Association in Scarborough. The growing realisation of the importance of basic fetal and neonatal physiology research to medicine, and also the increasing number of clinicians with a special interest in the newborn, had led to an invitation being extended to Geoffrey Dawes to present the Still Memorial Lecture at the British Paediatric Association's Spring Meeting in 1959.

Some of the key actors interested in the care and physiology of the newborn had been discussing the establishment of some sort of research discussion group, finding that both the British Paediatric Association's conferences and the meetings of the Physiological Society in London had become too large and general. It was also felt that such a group should include both scientists and clinicians. So in the basement of the Royal Hotel, Scarborough, Douglas Gairdner, a paediatrician from Cambridge, gathered together a number of paediatricians and scientists who he hoped would be interested in such a society.[602] This initial group included: Tom Stapleton (St Mary's, London); Robert McCance (Cambridge); A Holzel (Hammersmith); Peter Tizard (Hammersmith); John Forfar (Edinburgh); Hugh Jolly

601 McAdams, R. (2007). Interview with Professor John A Davis, 5th June
McAdams, R. (2007). Interview with Professor Alec Campbell and Professor Mike Tunstall, 27th August.

602 McCance, R. Sa/nns/f.3: 'the foundation and early years of the neonatal society'. *The Neonatal Society Archive [SA/NNS]. Archives and Manuscripts, Wellcome Library.* London.

(Great Ormond Street); Beryl Corner (Bristol); Professor Ronald S Illingworth (Sheffield); Mary Crosse (Birmingham) ; and Geoffrey Dawes (Oxford).[603] As Robert McCance described it:

> There was general agreement at once that some active little research society or club was highly desirable in Britain at that time, and a discussion followed on whether its interests should be general paediatrics or neonatal lore. Geoffrey Dawes rather swayed the meeting in favour of a neonatal society by pointing out that the physiologists and other scientists outside medicine would be much more likely to be interested in this. It was left to Tom Stapleton, Geoffrey Dawes and RA McCance to organize something as best they could.

Invitations were sent out to other like-minded clinicians and scientists. By the first meeting of the Neonatal Society, in November 1959, the fledgling group had thirty-six members.[604] McCance was elected as the first Chairman, with the organising committee also including Tom Stapleton, LE Mount, GEW Wolstenholme and Thomas Oppé. The first papers presented to the Society were given by Dawes and Cross on 'Changes in the oxygen consumption of monkeys after birth' and 'Reflex responses of the newborn infant to lung inflation' respectively.[605]

The Neonatal Society held several meetings per year in the early 1960s, and members were invited to present short papers on their research, followed by discussion. They also organized subject specific symposia. Society meetings provided a forum for the rapid dissemination of knowledge and discussion of research. Although created to provide a space where clinicians and scientists could discuss both the medical and scientific aspects of neonatal research, the society reportedly had an innately physiological bias.[606] It was organised, by McCance, on the model of the Physiological Society, with new members having to

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603 Christie, D. and E.M. Tansey. (Eds.) (1999). *Origins of Neonatal Intensive Care in the UK*. London, Wellcome Trust.p6.

604 McCance, R. Sa/nns/f.3: 'the foundation and early years of the neonatal society'. *The Neonatal Society Archive [SA/NNS]. Archives and Manuscripts, Wellcome Library.* London.

605 Ibid.

606 McAdams, R. (2007). Interview with Professor John A Davis, 5th June.
McAdams, R. (2007). Interview with Professor John Forfar, 19th June.
McAdams, R. (2007). Interview with Dr Herbert Barrie, 31st January.
McAdams, R. (2007). Interview with Professor Alec Campbell and Professor Mike Tunstall, 27th

present a paper before joining and it was by invitation or nomination only.[607] Although this was off-putting to some clinicians, the Neonatal Society became the forum for the reporting of the most important clinical and physiological work concerning the neonate during the 1960s and 1970s.[608]

The Society helped to foster collaborative relationships between clinicians and physiologists and cemented and expanded the neonatal network which developed in Britain at the time. It further provided an opportunity to develop the trans-Atlantic network of individuals interested in the neonate by inviting leading American researchers to give papers throughout the 1960s. The minutes of the young society illustrate that many of the Boston and New York neonatal researchers came to Britain during the early 1960s to present their work to the Neonatal Society, including, Clement Smith, Charles Cook, Mary-Ellen Avery and Stanley James.[609] The Society also became the forum for some of the debates surrounding newborn resuscitation which occurred during the 1960s.

The membership of the Neonatal Society represented the major actors in the neonatal network in Britain during the late 1950s and 1960s. All of whom played a major role in directing neonatal research and deciding neonatal care. The growing influence of this network will become more apparent in the following section and next two chapters, which examine the fate of two resuscitative techniques during the 1950s and 1960s

The neonatal network and newborn resuscitation during the early 1960s

As the elite group of clinicians and scientists interested in the newborn developed the neonatal network they began to form a consensus on how best to treat the

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607 McAdams, R. (2007). Interview with Professor John Forfar, 19th June.
This again illustrates the authority of physiologists in the development of the sub-specialty neonatology during the 1950s and 1960s.

608 McAdams, R. (2007). Interview with Professor John Forfar, 19th June
McAdams, R. (2007). Interview with Professor John A Davis, 5th June
McAdams, R. (2007). Interview with Professor Alec Campbell and Professor Mike Tunstall, 27th August.

609 Sa/nns/a/1: Minute book of the neonatal society a.G.M.S 1959-72. *The Neonatal Society Archive [SA/NNS]. Archives and Manuscripts, Wellcome Library.* London.

asphyxiated newborn during the early 1960s. Members of the network were in agreement that the most effective means of resuscitating a severely asphyxiated newborn was the use of positive pressure ventilation, with endotracheal intubation, and the use of a rubber bag the preferred method of administration. Network members also agreed that cases of asphyxia neonatorum should be divided into the mildly depressed and the more severely asphyxiated. This differentiation corresponded to different types of treatment. It was agreed that less severe cases, described as suffering from blue asphyxia or asphyxia livida, required stimulation, from suctioning the larynx and supplying oxygen via a face mask. Whereas the more severely asphyxiated, that is infants in white asphyxia or asphyxia pallida, required immediate intubation and positive pressure ventilation.

The neonatal network was in agreement that the future improvement of newborn care would be determined via a greater appreciation of neonatal physiology. As has already been discussed the network was not only composed of clinicians but also of eminent neonatal physiologists, who had a prominent voice in debates surrounding the care of the newborn. The network members therefore valued basic animal research both as a source of knowledge about the human fetus and newborn, as well as a means of assessing new treatments for the neonate.

One of the key changes in newborn resuscitation, which was quickly adopted and disseminated by the members of the neonatal network in the early 1960s, was the new technique of external cardiac massage. The adoption of this technique was in part due to its popularity in the resuscitation of adults, but also due to a growing appreciation of the central role of the heart and circulation in the establishment of respiration in the newborn. The first cases of external cardiac massage being applied to the asphyxiated newborn were reported in American medical journals towards the end of the 1950s.[610] By the 1960s more detailed reports of the successful application of the technique were found in the medical press, and it was soon viewed as another essential step in the resuscitation of the severely asphyxiated newborn.[611]

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Galos, G. and S. Surks (1957). "Cardiorespiratory arrest in the newborn treated by cardiac massage." *American Journal of Obstetrics and Gynecology* **74**(5): 1108-1111.
Halperin, M. (1957). "Queries and minor notes: Heart massage in a newborn infant." *JAMA*: 1996.

611

Kouwenhoven, W., J. Jude, et al. (1960). "Closed-chest cardiac massage." *JAMA* **173**(10):

Although the neonatal network was a fairly small and elite group of individuals during the early 1960s, some of its members did attempt to disseminate some of the knowledge that it generated to the rest of the medical community. Examples of these attempts can be found in the promotion of their preferred method of newborn resuscitation, and the promotion of neonatal physiology and calls for a more physiologically based approach to care of newborns.

The obstetrician Ian Donald published an article in the *British Journal of Anaesthesia* in 1960 lamenting the lack of an agreed protocol for treating asphyxia neonatorum.[612] Donald was the Regius Professor of Midwifery at the University of Glasgow. He had worked at St Thomas' after the war and had fostered an interest in the respiratory problems of the newborns, conducting some research on newborn resuscitation and ventilation, although his interests turned towards the fetus and the use of ultrasound during the 1960s.[613] He was also an early member of the Neonatal Society. In his 1960 article he complained that there was still much disagreement over who was responsible for resuscitating the newborn, suggesting that much of the tension was due to politics between medical specialists. He argued that it should be 'the urgent concern of whosoever is available to cope', be that the anaesthetist, obstetrician or paediatrician.[614]

Donald complained that:

> resuscitation techniques are as controversial as ever and range from procedures which are either heroic or bizarre…to the physically "dolce

1064-1067.
Moya, F. and E. D. Burnard (1961). "Current comment: Closed chest cardiac massage in the newborn." *Anesthesiology* **22**(4): 644-645.
Moya, F. and E. D. Burnard (1961). "Current comment: Closed chest cardiac massage in the newborn." *Anesthesiology* **22**(4): 644-645.
Sutherland, J. and H. Epple (1961). "Cardiac massage of stillborn infants." *Obstetrics and Gynecology* **18**(2): 182-186.
Moya, F., L. James, et al. (1962). "Cardiac massage in the newborn infant through intact chest." *American Journal of Obstetrics and Gynecology* **84**: 798-.
Thaler, M. and G. Stobie (1963). "An improved technic of external cardiac compression in infants and young children." *NEJM* **269**(12): 606-610.

612 Donald, I. (1960). "Asphyxia neonatorum." *British Journal of Anaesthesia* **32**: 106-115.

613 Lord, J., B. Powell, et al. (1953). "Treatment of asphyxia neonatorum." *Lancet* **2**: 1001-1004,
Donald, I. (1954). "Atelectasis neonatorum." *The Journal of Obstetrics and Gynaecology of the British Empire* **61**(6): 725-737,
Nicolson, M., J. Fleming, et al. (2005). "Hyaline membrane and neonatal radiology - ian donald's first venture into imaging research." *Scottish Medical Journal* **50**: 35-37.

614 Donald, I. (1960). "Asphyxia neonatorum." *British Journal of Anaesthesia* **32**: 106-115. p106.

> far niente" of those who believe that a baby's best chance in meeting the hazards of its birth is to be left strictly alone.[615]

Donald had become a member of the Neonatal Society in 1959, and was in agreement with the ethos that stressed the importance of basic physiological research for the improvement of neonatal care. This was apparent in his article which discussed at length current neonatal physiological research and its importance for assessing and choosing resuscitative techniques.

Donald argued that there were different types of asphyxia which required different treatments stressing the importance of the blood pressure and circulation. He referred to the milder form of asphyxia which were traditionally classified as 'blue' or 'livida', the baby showed a deep cyanosis and was therefore demonstrating that it had an adequate peripheral circulation.[616] Donald argued that the prognosis for these babies was good 'provided oxygen can reach its brain before it is too late'.[617] These infants required rapid clearing of the airways and supply of oxygen using a face mask.

Donald stressed the need to monitor the infant's pulse, as a slowing pulse indicated a more serious asphyxia and deteriorating condition. Infants with more severe asphyxia, previously described as 'white asphyxia' or 'pallida', appeared white and flaccid with rapidly failing heart beat. He argued that it would be more useful to describe this condition as 'foetal shock', as it gave a better picture of what was happening.[618] Donald described how it was over the treatment of these infants that most of the disagreement existed.[619] He recommended further clearing of the infant's airways and endotracheal intubation and intermittent positive pressure insufflation to expand the infant's bronchioles.[620] He was aware of Day's 1952 research, which advised the use of rapid high pressure bursts of oxygen,

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615 Ibid. p106.

616 Ibid. p110.

617 Ibid. p110.

618 Ibid. p110.

619 Ibid. p112.

620 Ibid. p112.

which were safer. He further critiqued some of the other techniques still used to treat ‘foetal shock’, such as intragastric oxygen, Eve’s rocking method, mouth-to-mouth, and the ‘do nothing’ approach.

Donald was not alone in his attempts to educate the medical community. In 1960 a substantial review of newborn respiration and respiratory problems was published by some of the Boston-based paediatricians.[621] It clearly spelled out the Boston group’s views on newborn resuscitation as well as clearly highlighting their belief in the importance of basic physiological research. They felt it was important to have a firm grounding in neonatal physiology before attempting to assess resuscitative measures, and so spent time discussing the current understanding of the establishment of respiration in the newborn. They discussed what was known about the mechanisms of lung expansion in a healthy newborn, and stressed the significance of the vascular changes at birth, including the filling of the pulmonary vascular system and its link to lung expansion.

The authors were Charles D Cook, of the Children’s Medical Centre, Mary-Ellen Avery and Herbert Barrie, who was then a visiting paediatrician from London. They can be identified as prominent members of the neonatal network which was gaining influence in both east coast America and Britain from the late 1950s. They were attempting to standardise the care of the asphyxiated newborn and referred to some of the basic principles which had been set out by the American Academy of Paediatrics. These included providing an adequate airway, via suction of mucus. If the infant failed to achieve regular and adequate respirations in two minutes, then oxygen should be supplied, either using a nasal catheter or an oropharyngeal airway. If there was still no response an endotracheal tube should then be inserted to supply oxygen. In the absence of any respiratory movements they agreed that oxygen could be supplied intermittently under positive pressure, of between 15 and 30 cm. H_2O.[622]

Barrie returned to Britain in 1960 completely convinced that intubation and positive pressure inflation was the most appropriate and effective method of resuscitating the newborn, having witnessed Virginia Apgar on several occasions successfully

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621 Cook, C., H. Barrie, et al. (1960). "Respiration and respiratory problems of the newborn infant." *Advances in Pediatrics* **11**: 11-80.

622 Ibid.

resuscitate a baby using intubation.[623] On his return he became aware of the lack of consensus on the issue of newborn resuscitation in Britain and set about trying to convince the medical community that the answer was intubation.[624] Throughout the 1960s, Barrie published widely on newborn resuscitation writing articles aimed not just at paediatricians and obstetricians, but also at midwives and general practitioners.[625] He felt that intubation was a skill that everyone concerned with treating the newborn should be taught to use. In 1963 he produced a short film which demonstrated his technique of treating the asphyxiated newborn, with detailed instruction on the intubation and positive pressure inflation. He promoted this across Britain at medical societies and meetings.[626] The film was accompanied by his seminal article in the *Lancet*, 'Resuscitation of the newborn' in March of that year.[627] It was unusual for the *Lancet*, a leading medical research journal, to publish an article on clinical practice. However, with the widespread concern over neonatal mortality, highlighted by the recent National Birthday Trust Fund Perinatal Mortality Survey, and the continued debates surrounding newborn resuscitation at the time, the editors obviously felt that the article warranted publication.

Through the article Barrie hoped to address the 'misconception' that intubation could only be accomplished 'with costly equipment and rare skill'.[628] He set out his system for newborn resuscitation at St Thomas' stressing that both the equipment and resuscitation techniques were simple to master. He provided detailed

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623 McAdams, R. (2007). Interview with Dr Herbert Barrie, 31st January.

624 Ibid.

625 Barrie, H. (1959). "Letter to the editor: Intragastric administration of oxygen." *Lancet* **1**: 884-885,
Barrie, H. and R. Bonham-Carter (1959). "Correspondence: Respiratory difficulties at birth." *BMJ*: 1183-1184,
Barrie, H. (1962b). "Respiratory stimulants in the newborn." *Lancet* **2**: 742-746,
Barrie, H. (1963). "Resuscitation of the newborn." *Lancet* **2**: 650-655,
Barrie, H. (1963). "Hyperbaric oxygen in resuscitation of the newborn." *Lancet* **2**: 1223-1224,
Barrie, H. and D. Barrie (1965). "Correspondence: Death by suction." *Lancet* **1**: 962,
Barrie, H. (1968). "Focus on the low birth weight infant. Part 1: Basis of modern management." *Midwife and Health Visitor* **4**: 326-328,
Barrie, H. (1968a). "Correspondence: Resuscitation of the newborn." *Lancet* **1**: 1033.

626 McAdams, R. (2007). Interview with Dr Herbert Barrie, 31st January.

627 Barrie, H. (1963). "Resuscitation of the newborn." *Lancet* **2**: 650-655.

628 Ibid. p650.

information on the set-up of a ‘resuscitation bay’ for babies and a list of all the equipment required, along with details of their maintenance.

Barrie’s article was met with praise and support by some converts to intubation and positive pressure. TR Steen, an anaesthetist from Southmead Hospital, Bristol, commented that ‘it is right that endotracheal intubation should be used more frequently, for it never does harm when correctly performed, and the inflation of oxygen by this route can be life-saving’.[629] Gerald Neligan, a paediatrician in Newcastle, was equally positive when he stated: ‘I should like to add my support to Dr Barrie’s plea that the most effective known method of resuscitation should be available for every asphyxiated baby delivered in hospital.’[630] However, not everyone shared this enthusiasm for intubation, as was evidenced by a letter from LG Higgins to the *Lancet* in response to the article.[631] Although Higgins found Barrie’s article interesting, he called for ‘proof of the value of these measures’.[632]

It was not only individual members of the neonatal network which tried to communicate its message to clinicians. In 1961 to mark the establishment of the Neonatal Society and one of its first symposia, the *British Medical Bulletin* published a special issue on fetal and neonatal physiology edited by Kenneth Cross. The then President of the Neonatal Society, Robert McCance, provided a short introduction to the issue, where he discussed the growing realisation of the importance of physiology for improving the care of the newborn, as he commented:

> Paediatricians suddenly woke up to the fact that hundreds of lives might be saved by applying the elementary principles of salt-and-water metabolism to infectious diarrhoea and the application of new techniques to the right animal made the respiratory physiology and the circulation of the foetus and new-born animal a living subject.[633]

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629 Steen, T. (1963). "Correspondence: Resuscitation of the newborn." *Lancet* **1**: 999.

630 Neligan, G. (1963). "Correspondence: Resuscitation of the newborn." *Lancet* **1**: 1049.

631 Higgins, L. (1963). "Correspondence: Resuscitation of the newborn." *Lancet* **1**: 999.

632 Ibid.

633 McCance, R. (1961). "Foetal and neonatal physiology: Introduction." *British Medical Bulletin* **17**(2): 79-80.

The remainder of the issue was comprised of several papers which had been presented at the Neonatal Society, by many of its members. The papers not only represented the array of different research interests the neonatal network members had, but also stressed the consensus that improved knowledge of newborn physiology would lead to improved care of the newborn. Papers were given by Kenneth Cross, Geoffrey Dawes and several members of Dawes' Nuffield research team. A paper of particular significance for our present concerns was given by John Davis and Peter Tizard on 'Practical problems of neonatal paediatrics considered in relation to animal physiology'.[634]

At this time Davis, a paediatrician, was working at the Nuffield Institute for Medical Research, Oxford, whereas Tizard was based in the Institute of Child Health, University of London. Both Davis and Tizard, as has been mentioned, were important members of the emerging neonatal network. Davis had qualified in medicine at St Mary's Hospital, and joined the paediatric unit in 1950. Having developed an interest in the newborn and neonatal physiology, he spent a year at the Boston Children's Medical Centre working with Charles Cook and also received a Research Fellowship to work with Dawes in Oxford.[635] He was therefore a strong believer in the importance of combining physiological and clinical research to improve newborn care. Tizard followed a similar path, also spending a year in Boston with Cook, and had spent a sabbatical in Oxford with Dawes, so it was unsurprising that the two had begun to collaborate.

As much as both Davis and Tizard agreed that physiology should be used to inform the care of neonate they were also aware of some of the problems this could create, explaining:

> The clinician who wishes to base his practice on physiology has two reasons for caution: the first that the findings in physiology are derived from experiments performed in precisely controlled conditions; the second, that findings in animals do not necessarily apply to man.[636]

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634 Davis, J. and J. Tizard (1961). "Practical problems of neonatal paediatrics considered in relation to animal physiology." *British Medical Bulletin* **17**(2): 168-173.

635 McAdams, R. (2007). Interview with Professor John A Davis, 5th June.

636 Davis, J. and J. Tizard (1961). "Practical problems of neonatal paediatrics considered in relation to animal physiology." *British Medical Bulletin* **17**(2): 168-173. p168.

These same concerns were held by the majority of clinicians during the early 1960s and were raised continually during debates surrounding newborn resuscitation at the time. Despite these problems Davis and Tizard remained convinced that progress would only be made in neonatal paediatrics when animal physiology research was related to clinical practice. One particular area where they felt this was greatly beneficial was in the treatment and understanding of birth asphyxia.

Like Ian Donald, Davis and Tizard described how the traditional blue and white types of asphyxia corresponded to mild and severe asphyxia, and discussed the differing physiology of both states, which had been elucidated through animal physiology.[637] They explained that: 'The state of blue asphyxia is characterized by apnoea and cyanosis, but the heart rate is normal or raised, the muscle tone is usually good'.[638] 'In contrast, in white asphyxia there is, in addition to apnoea and pallor, a heart rate below 100/min, invariably poor muscle tone.'[639] They agreed with Donald that those in blue asphyxia usually began spontaneous respirations after clearing of their airways and that if this was not the case then the situation would worsen and the baby would pass into white asphyxia.[640]

Having both contributed to and read the vast literature on experimental anoxia and asphyxia, both Davis and Tizard summarised some of the key findings. They described the consistent pattern of response across species to anoxia and asphyxia, which in the rabbit was as follows:

> At all ages, in most species, and whatever the protocol of the experiment, asphyxia or anoxia is followed in under a minute by a "crisis" characterized by apnoea, bradycardia and loss of muscle tone

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637 Asphyxia neonatorum had been considered to have two stages: asphyxia livida [blue] and asphyxia pallida [white] since at least the late nineteenth century (see:
Brothers, A. (1896). *Infantile mortality during childbirth and its prevention*. Philadelphia, P Blaikston, Son & Co,
Koplik, H. (1903). *The diseases of infancy and childhood. Designed for the use of students and practitioners of medicine*. London, Henry Kimpton,
Pfaundler, M. and A. Schlossman (1908). *The diseases of children. A work for the practicing physician*. Philadelphia & London, JB Lippincott.)

638 Davis, J. and J. Tizard (1961). "Practical problems of neonatal paediatrics considered in relation to animal physiology." *British Medical Bulletin* **17**(2): 168-173. p168.

639 Ibid. p168.

640 Ibid. p169.

> … Before the crisis there is usually increasing dyspnoea, and after the crisis the apnoeic period is followed by regular and spontaneous gasping.[641]

The onset of apnoea was characterised by slowing of the pulse and an eventual fall in blood pressure, which was accompanied by loss of muscle tone, colour change from livid to pale and eventual cessation of the spontaneous movements.[642] Further animal research found that newborn rabbits suffering from apnoea after the apparent crisis, could restore spontaneous respirations after stimulation, such as maintenance of an airway and supply of oxygen.[643] This same animal research demonstrated that 'a combination of cardiac massage and artificial ventilation will often restore to life an animal apparently dead'.[644]

Davis and Tizard argued that:

> [T]here are similarities on the one hand between asphyxia livida in the [human] infant and the apnoea that follows the anoxic crisis in the rabbit; and on the other between asphyxia pallida in the infant and the apnoea that succeeds the phase of gasping in the rabbit.[645]

They claimed that if these similarities were real then it would suggest that infants suffering from asphyxia livida should be treated by clearing of the airways and stimulation through an oxygen supply.[646] They further suggested that in cases of asphyxia pallida 'the need for effective artificial ventilation to prevent circulatory failure is urgent'.[647] Davis and Tizard therefore concluded that these 'experimental findings support accepted practice', or at least their accepted practice.[648]

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641 Ibid. p169.

642 Ibid. p169.

643 Ibid. p170.

644 Ibid. p170.

645 Ibid. p170.

646 Ibid. p170.

647 Ibid. p170.

648 Ibid. p170.

Thus, Davis and Tizard's protocol was very much informed by animal research on using experimental anoxia and asphyxia. They argued that 'most apnoeic new-born babies eventually breathe spontaneously and survive to be apparently normal children', although they admitted that 'this fact cannot be taken to justify inaction in cases of neonatal asphyxia'.[649] They therefore stated that: 'As in other emergency situations in which emotions are liable to vitiate judgement, it is as well to have a set routine for the resuscitation of the apnoeic infant.'[650] Davis and Tizard believed that babies in blue asphyxia were not in 'immediate danger', and should generally be treated through stimulation, such as suctioning the airways with a catheter, 'peripheral stimulation', or stimulant drugs.[651] Those infants in white asphyxia were considered to be in urgent need of oxygen, which should be introduced into the lungs, and cardiac massage.[652]

Davis and Tizard went further, using the animal experiments to explain the apparent success attributed to intragastric oxygen during the 1950s. They argued that:

> Its advocates… do not distinguish…between apparently successful applications of the method in which respiratory movements have preceded an improvement in colour, and those in which an improvement in colour precedes the onset of respiration. In the former case, the stimulation caused by passage of the gastric tube or inflation of the stomach has presumably been responsible, rather than the passage of O_2 across the intestinal wall.[653]

This employment of animal physiology to evaluate resuscitative techniques became a key factor in the changes in newborn resuscitation during the 1960s and will become more apparent in chapter 6 and 7.

It was not only members of the neonatal network who had reached a consensus on how best to treat the asphyxiated newborn. By the early 1960s anaesthetists

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649 Ibid. p169.

650 Ibid. p169.

651 Ibid. p169. Stimulant drugs were in vogue throughout the period the thesis has been considering, however they have not been discussed in any detail.

652 Ibid. p169.

653 Ibid. p169.

had also agreed that endotracheal intubation should be used. In 1961 the South-Western Obstetrical and Gynaecological Society held a meeting to discuss the role of the obstetrician, anaesthetist and the paediatrician in the management of obstetric problems.[654] The fourth session of the 1961 meeting addressed the specific problem of asphyxia neonatorum, and papers were presented by an obstetrician, an anaesthetist and a paediatrician.[655] At the meeting the anaesthetist, J Hamer-Hodge, of Portsmouth, viewed intubation as a routine procedure and claimed that he used it whenever an infant showed any sign of respiratory difficulty or apnoea in his hospital. Hamer-Hodge addressed some of the concerns surrounding the use of intubation on the newborn, describing some technical manoeuvres to aid in insertion of the endotracheal tube. He also discussed the concerns surrounding the possibility of barotrauma, arguing that newborns were just as likely to suffer a pneumothorax from their own inspiratory efforts as those which were treated with positive pressure insufflation.[656] Further examples of this promotion of intubation by anaesthetists can be found in individual articles in the medical journals during the early 1960s.[657]

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Barnett, T. and J. Foley, Eds. (1963). *The obstetrician, anaesthetist and the paediatrician in the management of obstetric problems. Transactions of the south-western obstetrical and gynaecological society's autumn meeting held at portsmouth 7-10 november 1961.* Oxford, Pergamon Press.

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Donald, I. (1963). "Asphyxia neonatorum - the obstetrician's viewpoint". in *The obstetrician, anaesthetist and obstetrician in the management of obstetric problems. Transactions of the south-western obstetrical and gynaecological society's autumn meeting held at portsmouth 7-10 november 1961.* T. Barnett and J. Foley (Ed.). Oxford, Pergamon**:** 109-124.
Rees, J. (1963). "Management of neonatal asphyxia". in *The obstetrician, anaesthetist and obstetrician in the management of obstetric problems. Transactions of the south-western obstetrical and gynaecological society's autumn meeting held at portsmouth 7-10 november 1961.* T. Barnett and J. Foley (Ed.). Oxford, Pergamon**:** 125-132.
Butler, N. (1963). "Complications of birth asphyxia with special reference to resuscitation". in *The obstetrician, anaesthetist and obstetrician in the management of obstetric problems. Transactions of the south-western obstetrical and gynaecological society's autumn meeting held at portsmouth 7-10 november 1961.* T. Barnett and J. Foley (Ed.). Oxford, Pergamon**:** 133-140.

656

Rees, J. (1963). "Management of neonatal asphyxia". in *The obstetrician, anaesthetist and obstetrician in the management of obstetric problems. Transactions of the south-western obstetrical and gynaecological society's autumn meeting held at portsmouth 7-10 november 1961.* T. Barnett and J. Foley (Ed.). Oxford, Pergamon**:** 125-132. p129.
Butler, N. (1963). "Complications of birth asphyxia with special reference to resuscitation". in *The obstetrician, anaesthetist and obstetrician in the management of obstetric problems. Transactions of the south-western obstetrical and gynaecological society's autumn meeting held at portsmouth 7-10 november 1961.* T. Barnett and J. Foley (Ed.). Oxford, Pergamon**:** 133-140. p139.

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Tunstall, M. (1964). "Neonatal resuscitation." *British Journal of Anaesthesia* **36**: 591-599.
Smith, B. (1965). "Resuscitation of the depressed newborn." *Anesthesiology* **26**: 549-561.

During the late 1950s and early 1960s in the USA there was a concern that cerebral palsy was linked to birth asphyxia. Concerns regarding the possible adverse effects of periods of prolonged asphyxia at birth have a longer history, with discussions in the medical literature dating back to the late nineteenth century, linked to the eugenics movement and concerns about ‘mental retardation’ and ‘deterioration’ of the population. However from the late 1950s the United States Government began to provide grants aimed at determining the possible causes of cerebral palsy, which in turn provided a boost to research into the physiology and treatment of asphyxia neonatorum.

As has already been mentioned, with a grant from the US National Institute of Child Health and Development, William Windle had formed an international team to investigate the aetiology of cerebral palsy in Puerto Rico in 1959. Believing that there was a link between cerebral palsy and birth asphyxia the researchers examined the fetal and newborn responses to asphyxia. This research elucidated detailed information on the changes in respiratory efforts, blood pressure, heart rate, and biochemistry of the blood during asphyxia, and identified a predictable series of physiological changes which occurred during asphyxia, which were comparable across species, and which could therefore be extrapolated to human infants.[658]

By the mid-1960s the Puerto Rican researchers had begun to disseminate their findings. One such publication appeared in the *New England Journal of Medicine* in 1964.[659] James and Adamson summarised some of the key physiological research findings of the Puerto Rico group on the various physiological and biochemical changes which occur both during the normal onset of respiration, and during asphyxia in newborns. By measuring the negative intrathoracic pressures induced by a healthy newborn monkey during its first and subsequent breaths, they were able to determine both the most effective and safest pressure which operators could use during positive pressure resuscitation.[660] Knowledge of the

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658 Liggins, G. (1998). “Geoffrey Sharman Dawes CBE.” *Biographical Memoirs of Fellows of the* Royal Society **44**: 110-125.

659 James, L. and K. Adamson (1964). "Medical progress: Respiratory physiology of the fetus and newborn infant." *NEJM* **271**(26): 1352-1360. This research was also described in The Paediatric Clinics of North America vol 13 (3) 1966 which was edited by LS James.

660 Ibid. p1357.

healthy newborn's initiation of respiration, had also informed researchers, such as Day, as to how long and at what rate these positive pressure impulses should be administered.[661]

The research, which used experimental asphyxia induced in newborn and fetal monkeys, had helped to deduce the physiological changes which occurred during birth asphyxia, which were found to be predictable.[662] Building on the earlier research of Tizard and Davis on rabbits, James and Adamson were able to prove that the same pattern of response to asphyxia occurred in higher primates which were more comparable to human babies.[663] James and Adamson described in detail the new physiological conception/construction of birth asphyxia which was divided into primary and secondary apnoea and were able to argue that this was of great clinical relevance for the both the assessment and treatment of asphyxia neonatorum. This conception was eventually widely accepted, and it is still used today when teaching medical personnel newborn resuscitation.

At the onset of asphyxia the newborn was seen to increase both the depth and rate of respiratory efforts for a few minutes, which was soon followed by primary apnoea, when respiratory efforts ceased for about one minute.[664] Rhythmic gasping then began, which in the newborn monkey could be maintained at a steady rate of six gasps per minute for several minutes.[665] However, the gasps became less frequent and weaker, and eventually stopped altogether. This second cessation of gasping marked the beginning of secondary apnoea.[666] Throughout the deterioration into secondary apnoea the heart beat was slowing, and by the time the animal reached secondary apnoea the heart may have been inaudible

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Day, R., A. Goodfellow, et al. (1952). "Pressure-time relationship in the safe correction of atelectasis in animal lungs." *Pediatrics, Springfield* **10**: 593-. This research has already been discussed in chapter 4.

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James, L. and K. Adamson (1964). "Medical progress: Respiratory physiology of the fetus and newborn infant." *NEJM* **271**(26): 1352-1360. p1358.

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Davis, J. and J. Tizard (1961). "Practical problems of neonatal paediatrics considered in relation to animal physiology." *British Medical Bulletin* **17**(2): 168-173.

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James, L. and K. Adamson (1964). "Medical progress: Respiratory physiology of the fetus and newborn infant." *NEJM* **271**(26): 1352-1360. p1358.

665

Ibid. p1358.

666

Ibid. p1358.

and the newborn would appear flaccid and pale, the appearance traditionally called white asphyxia or asphyxia pallida. James and Adamson argued that this same animal research had confirmed that newborns in primary apnoea could be resuscitated using a variety of stimuli, such as suctioning of the oropharynx.[667] However, in secondary apnoea the only known way of resuscitating these infants was by prompt artificial ventilation.[668]

So by the early 1960s the neonatal network was coming to a general consensus both on how the newborn suffering from asphyxia presented clinically, and also on how they should be treated with a particular emphasis on the importance of the circulation and heart beat as indicators of the stage of asphyxia and therefore the type of treatment required. However, this was only a consensus amongst members of the network which mainly consisted of academic paediatricians, obstetricians, anaesthetists and physiologists, who were drawn largely from the London Medical Schools, The Nuffield Research Institute and the universities of the east coast of America, including Harvard, Columbia and Yale, and their associated hospitals. But the majority of births were attended by clinicians who were not members of this small and elite network and they were less influenced by this basic animal research. Some non-network clinicians were sceptical of the extrapolation of such research to the clinic, whereas others still feared that the use of intubation was dangerous and demanded high clinical skills. Therefore amongst the majority of British clinicians responsible for treating the asphyxiated infant there was still no clear consensus on just how to resuscitate the neonate. This lack of consensus and the division which had emerged between the neonatal network and the rest of the British clinicians concerned with the newborn became very evident when two alternative resuscitative methods were advocated during the 1950s and 1960s. The fates of these methods, intragastric oxygen and hyperbaric oxygen, illustrate both the growing influence of the neonatal network and also the gulf which had opened up between the network members and the majority of British clinicians concerned with the care of the newborn. Intragastric oxygen and hyperbaric oxygen will be analysed in greater detail in the following two chapters.

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[667] Ibid. p1358.

[668] Ibid. p1358.

Chapter 6

A medical misadventure? The rise and fall of intragastric oxygen

Intragastric oxygen was a technique which became popular for the treatment of asphyxiated newborns during the 1950s. However, in more recent writings on the history of neonatal resuscitation intragastric oxygen is rarely mentioned. As has been mentioned in chapter 1, these writings normally take the form of brief historical introductions in medical textbooks, or historical reviews in medical journals, and are almost always written by clinicians. They tend to recount the struggles of the pioneers of positive pressure ventilation, who battled to convince clinicians of the merits of their technique.[669] Intragastric oxygen, if mentioned at all, is normally parcelled together with a number of other ‘deviations’, ‘misadventures’ or ‘setbacks’ in newborn resuscitation, serving only to delay the eventual and inevitable adoption of positive pressure ventilation, as the most appropriate resuscitative technique.[670]

An example of this sort of historiography can be seen in Hyman’s essay on neonatal resuscitation in the book *Anaesthesia – Essays on its History*.[671] Hyman, an anaesthesiologist, described how his predecessor, Joseph Kreiselman, pioneered the use of positive pressure ventilation for treating the asphyxiated newborn from the 1920s. However, due to a reluctance amongst paediatricians,

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Hyman, A. (1985). "History of resuscitation of newborn infants". in *Anaesthesia - essays on its history*. J. Ruprecht, M. J. Van Lieburg*et al* (Ed.). Berlin & Heidelberg, Springer - Verlag**:** 141-143,
Goldsmith, J. and E. Karotkin (1996). "Introduction to assisted ventilation". in *Assisted ventilation of the neonate*. J. Goldsmith and E. Karotkin (Ed.). Philadelphia, WB Saunders Co.**:** 1-19,
Raju, T. (1999). "History of neonatal resuscitation. Tales of heroism and desperation." *Clinics in Perinatology* **26**(3): 629-640,
O'Donnell, C., A. Gibson, et al. (2006). "Pinching, electrocution, raven's beaks, and positive pressure ventilation: A brief history of neonatal resuscitation." *Archives of Disease in Childhood. Fetal and Neonatal Edition* **91**: F369-373.

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Ibid.

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Hyman, A. (1985). "History of resuscitation of newborn infants". in *Anaesthesia - essays on its history*. J. Ruprecht, M. J. Van Lieburg*et al* (Ed.). Berlin & Heidelberg, Springer - Verlag**:** 141-143.

obstetricians, and their staff, to learn the technique, and also the absence of anaesthesiologists in the delivery rooms, a number of 'worthless systems of infant resuscitation', including intragastric oxygen, were used for another 40 years.[672] A further example of this can be seen in the introduction to the reprint of Cooper's 'classic' 1960 paper, 'On the efficiency of intragastric oxygen', which was published in a 1995 issue of *Anaesthesia*.[673] Cooper presents the fate of intragastric oxygen as a story of objective scientific investigation triumphing over subjective experiences. Thus it would appear that, to date, intragastric oxygen has been dismissed as a dangerous and inconvenient misadventure in the progressivist history of positive pressure ventilation for the resuscitation of the newborn infant.

This case study is intended to provide a more nuanced analysis of the fate of this long-forgotten technique by discussing the reasons why it gained rapid popularity during the early 1950s, and why it was eventually abandoned, with a particular emphasis on the role of social and non-scientific factors, including the role of the emerging neonatal network. This will provide an insight into some of the wider trends in the development of neonatology in Britain, and introduce some of the wider themes of later twentieth-century medicine.

The rise to popularity of intragastric oxygen

Like some of the other resuscitative techniques popularized during the 1950s, intragastric oxygen was originally advocated during the interwar years. The method was first suggested as a treatment for the asphyxiated newborn by the Finnish paediatrician Avro Ylppö (1887-1992) in 1934. As was discussed in chapter 2, Ylppö is most remembered for his contribution to infant pathology and physiology during the interwar years, whilst working in Germany, and has since been called the 'Archiater to Preemies'.[674] By the 1930s Ylppö had gained an international reputation as a pioneering authority in neonatal physiology and care, and had returned to Finland, taking up a chair in paediatrics at the University of Helsinki. It was at the sixth Northern Pediatric Congress, in Stockholm, in August

672 Ibid. in (Ed.).

673 Cooper, E. A. (1995). "On the efficiency of intragastric oxygen." *Anaesthesia* **50**: 535.

674 [Anon] (1957). "Archiater to preemies." *Time*: 11th Nov.

1934, that Ylppö first revealed his novel treatment for the respiratory problems of the neonate.[675]

Ylppö had first used intragastric oxygen ‘on the basis of the intestinal respiration found in certain species of fish’ (e.g. *Cobitis fossilis*), originally using it to treat apnoea of premature infants.[676] Ylppö was a contemporary of Barcroft and Henderson, who had also begun to use animal models to investigate the fetus and neonate during the interwar years. His theory was linked to developments in embryology and the belief that respiratory and digestive structures developed from the same cells in the embryo, and therefore retained some of the same properties in the newborn.

Ylppö’s technique involved passing a catheter into the infant’s stomach via the mouth and oesophagus, and administering oxygen at a rate of 3 or 4 litres per minute. He reported rapid improvement in his cases, and reasoned that oxygen absorption must have occurred in the gastric mucosa, as roentgenograms showed the presence and subsequent disappearance of oxygen in the neonatal abdomen, after administration of intragastric oxygen.[677] Ylppö argued that the oxygen could only have been absorbed into the stomach, dismissing the possibility of it passing through the bowels.[678]

Ylppö’s paper and his research aroused interest amongst clinicians and physiologists in the unique physiology of the newborn. Physiologists and clinicians began to report the presence of air in the stomach of newborns after only a few breaths, and others were inspired to investigate both the physiology of the phenomenon and also its significance. A Russian radiologist, JG Dillon, became very interested in gastro-respiration whilst working at the Roentgenological Institute of Moscow, during the early 1930s. Dillon presented his findings at the 5th

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675 [Anon] (1934) “The Proceedings of the sixth northern pediatric congress, Stockholm, Aug 27th-29th, 19342*. Acta Pediatrica* **17** supp 1: 1935.

676 Ylppö, A. (1935). "Über die behandlun der atemstörungen bei frühgeburten durch direkte zufuhr von sauerstoff in den magen." *Acta Paediatrica* **17**(Supp 1): 122-130,
Åkerrén, Y. and N. Fürstenberg (1950). "Gastro-intestinal administration of oxygen of asphyxia in the newborn." *Journal of Obstetrics and Gynaecology of the British Empire* **57**(5): 705-713.

677 Ibid.

678 Ibid.

International Congress on Radiology, Chicago in 1937 and later published this work in 1942 in the *American Journal of Roentgenology*.[679] His main interest concerned the prospect of using evidence of gastro-respiration detected roentgenographically, as medico-legal evidence in cases concerning infanticide and stillbirths. He spent a lot of time gathering evidence which supported the significance of gastro-respiration in the newborn, and therefore contributed significantly to the case for intra-gastric oxygen as a resuscitation technique.

The purpose of Dillon's paper was two-fold: he firstly wanted to establish that air was pulled into the stomach during respiratory movements; and secondly to establish the significance of air in the stomach. Dillon began by discussing evidence which confirmed that air was only found in the stomach of infants which had made some respiratory effort, and not in stillborn infants, and physiological evidence which confirmed that it was respiratory efforts which drew the air into the gut.[680] He concluded that:

> The finding of air in the stomach of the newborn after the first extra-uterine breath is so absolute, and at the same time roentgenographically so well established, that roentgenography must be acknowledged to be the most reliable means of determining whether an infant was born alive or was stillborn. It must also be counted as the most sensitive means of finding air in the stomach.[681]

Dillon then moved on to consider the significance of air in the stomach. He argued that air, and especially oxygen, would be freely absorbed into the blood.[682] Heclaimed that 'there is no anatomical impediment to such an absorption of oxygen through the walls of the digestive tract, as the digestive tract embryologically comes from the same anlage as the respiratory tract'.[683] Like Ylppö, Dillon drew on comparative physiology to support his claims, which provided 'indisputable proofs of an absorption of oxygen into the digestive tract of

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679 Dillon, J. (1942). "The respiratory function of the digestive tract as the basis of roentgenographic life test." *American Journal of Roentgenology* **48**(5): 613-624.

680 Ibid.

681 Ibid. p620

682 Ibid. p620

683 Ibid. p620

some vertebrates'.[684] Dillon further claimed that 'there are direct proofs of the possibility of using the digestive tract of a human organism as a respiratory organ'.[685] He made reference to the work of the German, J Kratter, who reported that post-mortem examination of infants who lived for several hours showed no air in the lungs but air was present in the digestive tract.[686] Although Dillon did concede that Kratter did not mention the possibility of gaseous exchange in the digestive tract, he claimed that 'it is quite clear that if the air entered the stomach and not the lungs, the oxygen feeding could take place only through the digestive tract'.[687] At a time when physiology was becoming increasingly viewed as relevant to medicine, and newborn care in particular, with the research of Barcroft, this research seemed compelling to many clinicians.

To further substantiate his claims Dillon then described two of his own cases which supported Kratter's findings. The first case concerned an infant, which lived for 25 minutes, but post-mortem exams found that the lungs were in a complete atelectatic state, whereas roentgenograms showed air in the stomach.[688] The second case lived for five hours, exerted feeble cries and was deemed to be in 'no need of any means to enliven it'.[689] A post-mortem exam found the lungs to be completely atelectatic, but a substantial amount of air in the stomach.[690] Using inductive reasoning he concluded that:

> … no other inference can be drawn from this fact than that the infant did not breath with its lungs at all and that it could live and even cry only by means of the air which was in its digestive tract and which could get there only by means of the respiratory movements of the thorax.[691]

684 Ibid. p620-621

685 Ibid. p621

686 Ibid. p621

687 Ibid. p621

688 Ibid. p621

689 Ibid. p622

690 Ibid. p622

691 Ibid. p622

Dillon argued that his evidence was enough to claim that 'the gastrointestinal respiration of man is well established', although he conceded that he could not comment on its significance in adults.[692] However, for newborns he argued that 'there is no doubt that the gastrointestinal respiration is a regular subsidiary gaseous exchange which begins to function during any disturbance or stoppage of the respiration of the lungs'.[693] Dillon's research reflects the attempts during the 1930s, discussed in chapter 2, to provide more objective and scientific evidence to support clinical practice, as it was felt that medicine needed to become more 'scientific'. However, his use of clinical case reports also highlights the fact that the subjective experience and clinical interpretation of clinicians was still considered important and relevant in directing and assessing clinical practice during the interwar years.

It is clear that Dillon's interest in gastro-respiration in newborns was more to do with assigning medico-legal authority to his profession in ascertaining whether an infant was born dead or alive, using roentgenography. However his paper had an impact on those interested in intragastric oxygen therapy. Two key papers were published during the early 1950s, which served to raise the profile of intragastric oxygen for the resuscitation of newborns. Both papers took the form of uncontrolled trials, or rather a compilation of case reports. Just like the interwar years, during the early 1950s subjective evaluation of clinical practice, in the form of case reports, was still considered a valid and significant means of assessing different techniques, although there was an increase in attempts to embrace the scientific method in medicine.

The first paper was co-authored by a paediatrician from Sweden, Yngve Åkerrén (1895-1957), who had attended the 1934 conference at which Ylppö presented his original paper. Having heard Ylppö's paper and read Dillon's research, Åkerrén had been inspired by the novel method and had begun to consider using it to treat asphyxiated newborns in his hospital in Gothenburg. However Åkerrén's enthusiasm was inhibited by the initial scepticism of some of his more senior colleagues, who preferred the use of other measures. The favoured treatment for

692 Ibid. p622

693 Ibid. p622

the asphyxiated newborn in Sweden during the 1930s and 1940s was mouth-to-mouth resuscitation and contrast baths. Åkerrén at first was only allowed to use the technique alongside this more established traditional approach.[694] However, 'confidence in the technique increased gradually', so by 1950 Åkerrén was finally able to publish a fairly substantial data set.[695]

Åkerrén was the chief clinician at the Children's Hospital, at the Sahlgrenska Hospital, Gothenburg, and had begun to work with the obstetrician Nils Fürstenberg, the Assistant Chief Clinician of the lying-in ward of the same hospital. They published a report of seven clinical cases of asphyxia neonatorum, which had been treated using Ylppö's method of intragastric oxygen, in the *Journal of Obstetrics and Gynaecology of the British Empire* in 1950.[696] It is interesting to note that this collaboration between an obstetrician and paediatrician highlights the involvement of a number of medical specialties in the care of the newborn, as was discussed in chapter 4.

As has been mentioned, by 1950 endotracheal intubation with positive pressure was becoming a popular treatment for the asphyxiated newborn in America, with proponents such as the obstetricians Joseph De Lee and JP Greenhill and the anaesthesiologist Paluel Flagg.[697] However opinion in America and Europe was still divided over its safety and the skill required to administer the treatment, with specific concerns surrounding the risk of pneumothorax.[698] Even the leading advocates had admitted that 'the alveoli cannot be effectively widened without the

694 Åkerrén, Y. and N. Fürstenberg (1950). "Gastro-intestinal administration of oxygen of asphyxia in the newborn." *Journal of Obstetrics and Gynaecology of the British Empire* **57**(5): 705-713.

695 Ibid.

696 Ibid.

697 Ibid.

698 Ibid.
Coryllos, P. (1931). "Atelectasis, asphyxia and resuscitation in the newborn." *American Journal of Obstetrics and Gynecology* **21**: 512-525,
Bloxsom, A. (1951). "Asphyxia neonatorum: A new method of resuscitation." *JAMA* **146**(12): 1120-1124,
Storah, P. (1951). "Apparatus for resuscitation of the newborn." *Irish Journal of Medical Science* **6**(306): 289-292.

aid of spontaneous breathing'.[699] So it was within this context that the Swedish clinicians felt that intragastric oxygen would be a viable alternative treatment for the asphyxiated neonate, arguing that it:

> … would facilitate the administration of oxygen despite apnoea and insufficient respiration, respectively, and primary atelectasis of the lungs, at the same time being technically simple and not carrying the risks associated with the tracheal methods.[700]

Although influenced by Ylppö's original paper, Åkerrén and Fürstenberg had adapted the technique by adding a second catheter. Aware of the possible danger of over-inflating the stomach, and therefore interfering with the diaphragm, they used one catheter for oxygen supply, whilst the second acted as a safety valve for out-flow.[701] They also advocated periodic inspection of the abdomen for undue distension.[702] If the oxygen was seen to be bubbling out of the second catheter and the stomach was not unduly distended, then oxygen was allowed to flow at 3 or 4 litres per minute, and they claimed that within 15 seconds both the stomach and intestines were filled, providing 'a considerable oxygen depot'.[703] Unlike Ylppö, who feared that the oxygen would pass straight through the bowels and would therefore be lost to the baby, Åkerrén and Fürstenberg viewed the bowels as an excellent site for absorption of oxygen.

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699 DeLee, J. and J. Greenhill (1947). *Principles and practice of obstetrics, 9th edition*. Philadelphia & London, WB Saunders Ltd.

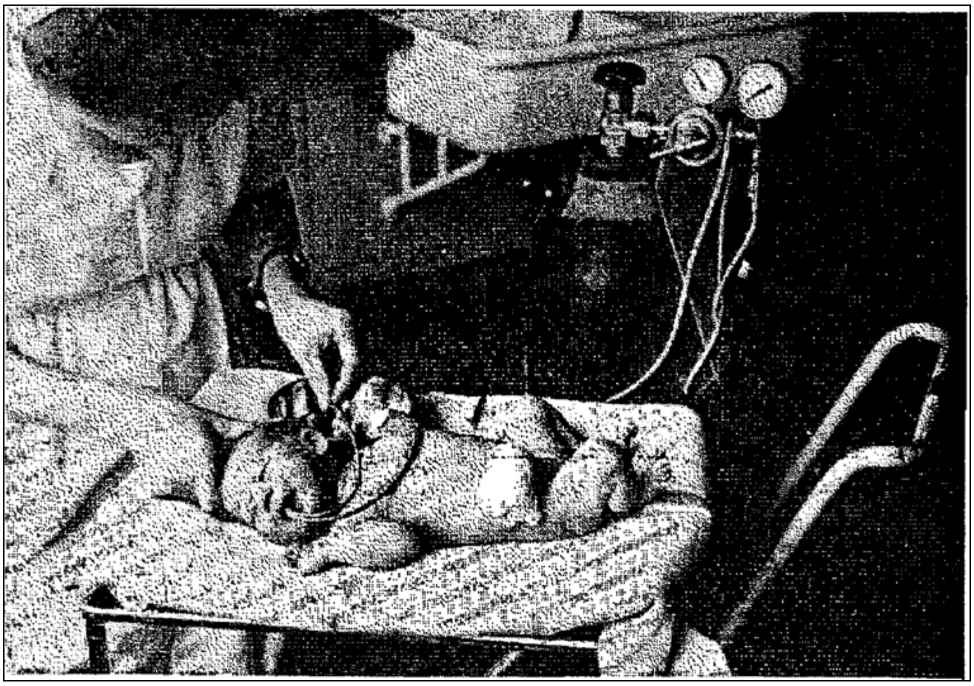
700 Åkerrén, Y. and N. Fürstenberg (1950). "Gastro-intestinal administration of oxygen of asphyxia in the newborn." *Journal of Obstetrics and Gynaecology of the British Empire* **57**(5): 705-713.

701 Ibid.

702 Ibid.

703 Ibid.

Figure 14. Image of infant being treated with intragastric oxygen. Image is taken from Åkerrén and Fürstenberg (1950) 'Gastro-intestinal administration of oxygen of asphyxia in the newborn', Journal of Obstetrics and Gynaecology of the British Empire, v57(5), p705-713.



It would seem that Åkerrén and Fürstenberg had to push for the introduction of intragastric oxygen, as they stated that they repeatedly advocated it at conferences throughout the 1940s, whilst raising doubts over the efficacy of the more established methods.[704] Their sustained effort gradually led to the introduction of intragastric oxygen at their hospital, alongside the conventional methods. By 1947, they claimed that intragastric oxygen was gaining popularity and was increasingly being used as the preferred method.[705]

Due to the initial scepticism, most of the early cases were first treated with other methods such as, 'contrast baths, manual artificial respiration, injection of stimulants, inter alia lobelin and tonocard'.[706] However, as confidence grew in intragastric oxygen Åkerrén and Fürstenberg were able to gather a number of 'pure' cases, which were primarily treated with intragastric oxygen. By that stage the established protocol at the hospital involved swaddling the infant on delivery, whilst gently rubbing and aspirating both the mouth and pharynx. If the infant still showed signs of asphyxia, intragastric oxygen was then given. If the infant's colour and tone improved, intragastric oxygen was replaced with oxygen therapy via a

704 Ibid. p707

705 Ibid. p707

face-mask. If, however, no improvement was evident, other methods such as respiratory stimulants were given.[707] Even when resort was had to other methods when intragastric oxygen was unsuccessful, Åkerrén and Fürstenberg were keen to reaffirm the efficacy of intragastric oxygen by pointing out that these cases mostly ended in the death of the child, thereby implying that if intragastric oxygen did not work, nothing else would.[708]

Again detailed subjective case reports were used to support the efficacy of the technique.[709] As has been mentioned during the 1950s this was an accepted means of assessing clinical practice. Åkerrén and Fürstenberg's 1950 paper along with a paper published in the *Lancet* in 1953, which provided another series of encouraging case reports, contributed to the rapid uptake of the technique during the early 1950s.

The *Lancet* paper was written by two London-based paediatricians, Harold Waller and David Morris.[710] Waller and Morris worked at the British Hospital for Mothers and Babies, and had first been introduced to the technique when Yngve Åkerrén visited their hospital in 1949.[711] Interestingly, Waller and Morris's paper suggests that there was also scepticism about the use of intragastric oxygen in Britain during the early 1950s. They framed their first use of the technique in a way that empathized with a sceptical reader. When Åkerrén first described the technique to them they thought, 'the notion of inflating the stomach of a severely shocked baby was startling … The project seemed impractical as well as involving risk'.[712] They further emphasized this feeling:

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706 Ibid. p708

707 Ibid. p708

708 Ibid. p708

709 Ibid. p708.

710 Waller, H. and D. Morris (1953). "Resuscitation of the newborn with intragastric oxygen (akerren's method)." *Lancet* **2**: 951-953. p951.

711 Ibid.

712 Ibid. p952

> … even when the opportunity arose [to test the technique], this instinctive reaction, so comfortably rationalised, still delayed trial of the method until its chance of success had become about as unfavourable as possible. It is chastening to think that had it failed on that occasion, we should have been more than ever tempted to reject it finally.[713]

Again, like Åkerrén and Fürstenberg, Waller and Morris argued that none of the numerous treatments advocated for neonatal resuscitation had received universal approval. They further claimed that ‘the present tendency is towards gentle rather than vigorous stimulation; but on the other hand, the apparatus and procedure devised for producing this stimulation have tended to become increasingly complex’, whereas they believed what was needed was a ‘simple, safe, and effective’ method.[714] Waller and Morris, like Åkerrén and Fürstenberg, believed that intragastric oxygen met these requirements and began to use it to treat severely asphyxiated newborns.

As already mentioned, the London doctors were initially sceptical, and so it was many months before they attempted to use it. In fact when they did finally use the method it was as a last resort in what was seen as an otherwise hopeless case. The baby was born:

> … white and toneless, mouth was aspirated, cord cut, oxygen given to mouth via a tube. Infant was gasping but over 30min they became weaker and less frequent. By an hour heart rate was irregular and slow.[715]

It was at this point that they decided to try intragastric oxygen. They stated that within two minutes the:

> … infant became pink, and full regular respirations were established with dramatic rapidity. Thereafter the baby gave no cause for further

713 Ibid. p952

714 Ibid. p951

715 Ibid. p952

> anxiety and when last seen at 3 years of age he appeared to be developing normally.[716]

After this apparent success Waller and Morris continued to use intragastric oxygen whenever a severely asphyxiated infant did not respond to their routine procedures. This led to an accumulation of 48 consecutive cases which were treated with intragastric oxygen, 41 of which were resuscitated.[717] With the growing support for the technique, the normal delivery room procedure at the British Hospital for Mothers and Babies, London, by 1953, involved[718]:

- When the head was born, the inside of the mouth was wiped carefully with square of soft linen, and then aspirated with a mucus extractor.
- When the baby was fully born, the cord was tied and cut, the infant was placed in a warm cot with small pillow humped into the loins and its head slightly lower than the feet.
- Aspiration was repeated if necessary.
- If respiration was delayed, gentle traction was applied to the tip of the tongue [Labrode method].
- If infant still did not breath, or only gave occasional gasps, with a falling heart rate, i.e. the severely asphyxiated, intragastric oxygen would be resorted to.

Waller and Morris' paper again illustrated one of the reasons that intragastric oxygen became so popular, the fact that it was viewed as a safe and simple method, or at least safer and simpler than intubation and the other mechanical resuscitative devices such as the Drinker respirator and Bloxsom air lock. So much so that Waller and Morris believed that even nurses could be entrusted to

716 Ibid. p952
717 Ibid. p953
718 Ibid. p952

use it.[719] They felt it was so safe that they had designed a home kit, which could be used in domiciliary care by midwives and general practitioners. The equipment was made commercially available, which contributed to the rapid dissemination of the technique in Britain. However Waller and Morris also stressed that the apparatus could be easily assembled from equipment already available to most clinicians in hospitals and domiciliary practice, which again increased its accessibility and emphasised its simplicity.

Waller and Morris used two different arguments to justify their research. In their discussion they referred to the physiology of the newborn, arguing that ‘in spite of the large amount of experimental work, the way in which respiration is initiated in the newborn infant is still not clearly understood’.[720] They stated that Clement Smith, Professor of Paediatrics at Harvard and author of the influential textbook *The Physiology of the Newborn Infant*, claimed that anoxia and sensory stimuli were the main factors involved, and that prolonged anoxia led to further depression, and therefore, the aim of any treatment is to supply oxygen to prevent prolonged anoxia.[721] Waller and Morris argued that the rapidity of absorption of oxygen from the gastro-intestinal tract ‘has been conclusively demonstrated’, and therefore intragastric oxygen fulfils the requirements of a resuscitative method.[722] Their second argument regarded the ethics of controlled trials in neonates. They admitted that the most conclusive way to determine the efficacy of a technique was to perform a controlled study. However they explained that ‘once it [intragastric oxygen] was found to be clinically effective, it became impossible to withhold it from any infant who might be benefited’.[723] Although they were aware there was a move towards more objective and scientific assessment methods, which they did attempt to incorporate with their reference to relevant physiological research, Waller and Morris ultimately rejected the purely objective assessment of the technique on ethical grounds. They preferred to present their subjective

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719 Ibid. p952

720 Ibid. p953

721 Ibid. p953. Clement Smith was introduced in chapter 2 as a contemporary of Barcroft. As Professor of Paediatrics at Harvard he was also influential in the neonatal network in the East coast of America (see chapter 5).

722 Ibid. p953

723 Ibid. p953

experience of using the technique in the form of case reports which, as has been mentioned, were still considered compelling evidence in the early 1950s.

Both these papers contributed to the rapid uptake of intragastric oxygen in Britain during the 1950s, and also to the wider adoption of the technique throughout Western Europe and America. It seems that no further questions were raised over the efficacy or safety of intragastric oxygen as it soon appeared in journal articles and medical textbooks as common practice. At a time when the care of newborns was becoming increasingly technical/mechanical it would appear that the simple and accessible technique of intragastric oxygen appealed to those clinicians and midwives who attended the majority of births at home or in smaller hospitals, which did not have access to the pulmotors and resuscitators of the larger teaching hospitals.

Evidence that the technique quickly gained popularity in Britain is demonstrated by the articles by British clinicians, which appeared in the medical journals during the early 1950s. As early as 1951 an Essex-based obstetrician, E Ostry, published a short paper in the *Journal of Obstetrics and Gynaecology of the British Empire*.[724] Owing to the fact that intragastric oxygen was ‘being increasingly practiced’ in Britain, Ostry had developed a modification of Åkerrén and Fürstenberg’s technique, which he claimed improved its safety.[725] Ostry had identified a number of disadvantages with Åkerrén and Fürstenberg’s technique: the two tubes may lie in different locations inside the infant; soft tubes can curl; overly stiff tubes may lead to perforation of soft tissue; and if tubes are too large they may compress the trachea and therefore embarrass respiration once it is established.[726] He therefore suggested replacing the two separate catheter tubes with a 24-inch length cut from an old Millar-Abbott tube.[727] The Millar-Abbott tube was divided in two internally,

[724] Ostry, E. (1951). "Instrument for gastro-intestinal administration of oxygen in asphyxia of newborn." *Journal of Obstetrics and Gynaecology of the British Empire* **58**(6): 1034.

[725] Ibid.

[726] Ibid.

[727] A Millar-Abbott tube is a double-lumen intestinal tube with an inflatable balloon at its distal end. It is commonly used for diagnosing and treating obstructions of the small intestine. The tube is inserted via a nostril and passed through the stomach and into the small intestine.

and according to Ostry it had the appropriate consistency: flexible enough not to damage soft tissue, whilst stiff enough to manipulate.[728]

Other evidence of the technique's rapid popularity can be found in reports from obstetricians working at Hammersmith Hospital during the 1950s. As already described, Hammersmith was fast becoming the leading clinical research hospital in Britain, and pioneering work on neonatal resuscitation and ventilation was being conducted there during the 1950s.[729] Yet, reports from Hammersmith-based clinicians indicated that intragastric had become standard practice there for the treatment of asphyxiated newborns, especially premature infants.[730] Although Hammersmith was one of the earliest British hospitals to advocate the use of positive pressure ventilation in newborn resuscitation, it was still deemed too dangerous for the more delicate premature infants. Josephine Lord, a research assistant in the Department of Obstetrics and Gynaecology at Hammersmith, commented that: 'Experience has taught us that endotracheal intubation is not a satisfactory treatment for small premature babies'.[731] They had therefore used gastrointestinal oxygen routinely since June 1952 for 'the routine treatment of apnoea in premature infants, and every infant so treated has become pink'.[732]

Ian Donald, who was then a Reader at the Institute of Obstetrics and Gynaecology, Hammersmith, and in receipt of a research scholarship form the Royal College of Obstetricians and Gynaecologists on the topic of newborn respiration, also discussed the practice at Hammersmith in his 1954 Blair-Bell Lecture at the College.[733] His lecture mainly discussed the physiology of

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728 Ostry, E. (1951). "Instrument for gastro-intestinal administration of oxygen in asphyxia of newborn." *Journal of Obstetrics and Gynaecology of the British Empire* **58**(6): 1034.

729 Reynolds, L. and E.M. Tansey. (Eds.) (2000). *Clinical Research in Britain, 1950-1980*. London, Wellcome Trust.
Booth, C. (1985). "Medical science and technology at the Royal Postgraduate Medical School: The first 50 years". *BMJ* **291**: 1771-1779.

730 Lord, J., B. Powell, et al. (1953). "Treatment of asphyxia neonatorum." *Lancet* **2**: 1001-1004, Donald, I. (1954). "Atelectasis neonatorum." *The Journal of Obstetrics and Gynaecology of the British Empire* **61**(6): 725-737.

731 Lord, J., B. Powell, et al. (1953). "Treatment of asphyxia neonatorum." *Lancet* **2**: 1001-1004.

732 Ibid.

733 Donald, I. (1954). "Atelectasis neonatorum." *The Journal of Obstetrics and Gynaecology of the British Empire* **61**(6): 725-737.

atelectasis neonatorum, and his own research into its treatment using a negative pressure ventilator. Although he reported that ‘the use of gastric oxygen is fairly widely employed’ at Hammersmith, he also raised some concerns over its general effectiveness.[734] In his words: ‘You can take a horse to water but you cannot make it drink’, that is to say that gastric oxygen was effective at oxygenating the baby, but not at ventilating, which was imperative for the removal of carbon dioxide.[735]

Åkerrén continued to publish papers on the use of intragastric oxygen, and its popularity continued to grow throughout the 1950s.[736] By the mid- to late-1950s it would appear that intragastric oxygen had been accepted as an effective treatment for asphyxia of the newborn. It repeatedly appeared in reports on the treatment of asphyxiated newborns, and was no longer being questioned or considered an experimental technique. Examples of this can be found in papers by obstetricians, paediatricians and anaesthetists in some of the leading medical journals of the time, such as those by Holmes and Payne, Bullough, and Johnson.[737] Other major advocates of intragastric oxygen included Douglas Gairdner, editor of the textbook *Recent Advances in Paediatrics*. In the 1954 edition of the textbook Gairdner commented that:

> That significant amounts of oxygen are in fact absorbed in this way seems unquestionable when the method is tested in practice. Apnoeic infants with deep cyanosis are generally changed within a minute into pink but still apnoeic infants, and after a further interval breathing begins.[738]

Intragastric oxygen not only gained popularity in Britain, its popularity also spread internationally, with advocates emerging in France, Israel and especially in the

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734 Ibid. p733

735 Ibid. p733

736 Åkerrén, Y. (1954). "A simple device for oxygen therapy of infants particularly in asphyxia neonatorum." *An International Journal of Obstetrics and Gynaecology* **61**(4): 477-479, Åkerrén, Y. (1954). "[asphyxia, shock and gastrointestinal oxygen therapy in the newborn]." *Nordic Medicine* **52**(51): 1759-1759.

737 Holmes, J. and J. Payne (1955). "Asphyxia pallida responding to endotracheal insufflation after 140 minutes." *BMJ*: 1071,
Bullough, J. (1958). "Protracted foetal and neonatal asphyxia." *Lancet* **1**: 999-1000.
Johnson, B. (1959). "An infant resuscitation trolley." *BJOG: An International Journal of Obstetrics and Gynaecology* **66**(3): 492.

738 Gairdner, D., Ed. (1954). *Recent advances in paediatrics*. London, J & A Churchill. p25.

United States.[739] Perhaps one of the most useful ways of seeing how much a technique had been accepted by the medical community is to look at the medical textbooks of the period. Unlike journal articles, which mainly report on novel and experimental techniques, textbooks tend to represent more standard and accepted practice. The widespread acceptance of intragastric oxygen as a valid treatment for asphyxiated newborns, is also evident in some of the leading paediatric and obstetric textbooks of the time including JP Greenhill's popular textbook *Principles and Practice of Obstetrics* and Wilfred Sheldon's *Diseases of Infancy and Childhood*.[740]

Intragastric oxygen was viewed as a simple alternative to the increasingly complex, skilled and technological resuscitative techniques which were being advocated after the war. This view that newborn resuscitation was becoming increasingly technological and skilful was also held by others who offered their own methods and routines for the care of the asphyxiated newborn in the pages of the medical journals during this decade, which has already been discussed.

The rise in popularity of intragastric oxygen also reflects some of the other themes apparent in the care of the newborn after the War. There was a growing awareness amongst clinicians that physiological research was relevant to their clinical practice. This growing awareness was reflected in the increasing trend of discussing advances in neonatal physiology when describing or assessing the clinical care of the newborn, specifically the asphyxiated newborn. There was also mounting evidence in these articles that clinicians were reluctantly accepting that the 'scientific method' of objectively assessing clinical practice was reliable. However, many still believed that these methods could not be directly applied to medicine, as they raised many ethical issues, specifically in the care of the asphyxiated newborn. More interesting are the themes which emerge when the fall of intragastric oxygen during the late 1950s and early 1960s is analysed.

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Fleury, J. (1953). "Oxygen treatment via stomach for anoxia." *Nourisson* **41**: 141-143,
Toaff, R. and B. Eckerling (1954). "Gastrointestinal administration of oxygen in asphyxia of the newborn." *Obstetrics and Gynecology* **3**(4): 366-370.

740

Greenhill, J. (1955). *Principles and practice of obstetrics*. Philadelphia & London, WB Saunders,
Sheldon, W. (1955). *Diseases of infancy and childhood*. London, J & A Churchill Ltd.

The gradual decline of intragastric oxygen

The first published attack on the efficacy of intragastric oxygen did not appear until 1959.[741] The pioneering neonatal research group at Columbia University, New York, led by Leonard James and Virginia Apgar, had begun to examine the physiological basis of intragastric oxygen, having become concerned by its rapid rise to popularity both in Britain and the United States. As has already been mentioned the Apgar-led group at Columbia University, New York, had become an important voice in newborn resuscitation and care by the mid-1950s and constituted part of the emerging neonatal network, which was gaining influence by the end of the decade. Apgar was the Professor of Anaesthesia, and her department had forged an important collaborative relationship with the Department of Paediatrics, headed by Professor Harold Abramson. Leonard James was a paediatrician, and a member of Professor Abramson's department.

The letter, published in the *Lancet,* detailed a single case in which a 20 week old fetus, weighing just 400g, was treated with tracheal intubation and positive pressure ventilation and intragastric oxygen. When treated with the former, the Columbia group reported that 'within seconds the skin became pink, tone and movements appeared in limbs, and regular respirations ensued'.[742] The fetus showed 93% oxygen saturation, pH of 7.24 and aortic pressure was 33 centimetres of water.[743] When the endotracheal tube was occluded and intragastric oxygen was administered, both the oxygen saturation and pH of the blood began to fall and 'the infant appeared dusky and limp'.[744] However 'upon reopening the endotracheal tube and re-oxygenating the lungs the infant dramatically recovered. His oxygen saturation rose to 94% and his pH to 7.25'.[745] The authors concluded that: 'in view of the many clinical impressions regarding the efficacy of intragastric

741 James, L. S., F. Moya, et al. (1959). "Letter to the editor: Intragastric administration of oxygen." *Lancet* **1**: 737.

742 Ibid.

743 Ibid.

744 Ibid.

745 Ibid.

oxygen for resuscitation, these findings are somewhat thought-provoking'.[746] It was clear that the Columbia group were letting the evidence speak for itself. This letter also led to a stream of further criticisms of the technique over the following five years.

As has been mentioned the growing American neonatal network also began to develop links with Britain during the 1950s. One way that this was facilitated was through the series of research fellowships granted to British clinicians after the War to spend time in American Universities. Herbert Barrie, who was introduced in the previous chapter, was a Senior Registrar at St Thomas' Hospital London, who had been awarded a Harvard Research Fellowship in Boston in the late 1950s, where he was soon convinced of the efficacy of intubation. So when Barrie wrote to the *Lancet* in response to James *et al*'s letter, in April 1959, he had already been indoctrinated into this neonatal network and their agreed methods.[747]

In the letter his admiration for the Columbia group was evident, as was his frustration with the empirical basis of a lot of the treatments provided for neonates.[748] Barrie stated that:

> In the past 5 years, intragastric oxygen has gained ready and widespread acceptance as a method of resuscitation, which is surprising in view of the virtual non-existence of any objective evidence in its favour. [749]

He then continued to critique each of the studies which were claimed to support the use of intragastric oxygen, and the physiological research that they employed. Although he argued that Åkerrén and Fürstenberg made 'the first (and only) substantial contribution' to the debate, his tone soon turned sarcastic as he commented that 'they described 7 cases and attempted to substantiate the favourable outcome by an ingenious theoretical argument'.[750] Although he appeared to commend their attempts at engaging with physiological research, he

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746 Ibid.

747 Barrie, H. (1959). "Letter to the editor: Intragastric administration of oxygen." *Lancet* **1**: 884-885.

748 Ibid.

749 Ibid.

750 Ibid.

thought it unfortunate that the physiological research they had chosen was not applicable.[751] He commented:

> Unfortunately, all this is based on a figure derived by McIver *et al* on injecting 25c.cm [cm^3] into an isolated loop of cat intestine 30 years ago. There appears to be no recent human or animal data on the transfer of oxygen in unobstructed stomach or intestine, nor any evaluation of such variables as intraluminal pressure, portal blood flow, or the presence of mucus, meconium, and other substance'.[752]

Barrie was equally critical of Waller and Morris' attempt, which although reported 'enthusiastically', lacked any real scientific rigour.[753] Barrie totally disagreed with Waller and Morris' defensive argument that the procedure could only truly be tested by a controlled study, which was ethically unjustified in the situation. Barrie stated that 'to the scientific sceptic, some objective assessment such as oximetry, or even only the demonstration of a measured difference in the oxygen and carbon-dioxide content of the entering and returning gas, would have been infinitely more welcome' than the subjective/empirical evidence supplied.[754]

Barrie then continued to discuss the physiological evidence which suggested that intragastric oxygen was of no clinical use. He argued that the gastrointestinal tract lacked the surface area and the intimate alveolar-capillary architecture of the lungs and that portal blood-flow would not be sufficient to make gastric respiration viable, and stated that the lung has been shown to be 'an infinitely superior oxygenator'.[755] He further questioned the clinical evidence presented in the case reports, especially whether the infants turned pink before or after respirations had initiated.[756] If the infants turned pink after they had begun to breathe, this improvement could not necessarily be attributed to intragastric oxygen. Barrie

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751 Ibid.

752 Ibid.

753 Ibid.

754 Ibid.

755 Ibid.

756 Ibid.

further argued that the successful cases attributed to the treatment were more likely due to the insertion of two catheters, which was:

> … probably the most potent sensory stimulant permissible in modern standards of neonatal care, and I am personally convinced that any benefit derived from this method of resuscitation is attributable to this powerful stimulus to respiration.[757]

Barrie's final assault on intragastric oxygen regarded its 'alleged safety', which he feared was partly responsible for its popularity.[758] He listed a series of safety problems associated with the technique, including: obstruction of the tubes by mucus; over distension of the bowels; and interference with the infant's diaphragm.[759] However, Barrie's main objection to intragastric oxygen was that 'it often detracts from the institution of more effective means of resuscitation, and for this reason alone it should henceforth be abandoned'.[760] This letter was very damning to the advocates of intragastric oxygen and also highly critical of those who were sceptical of the merits of physiological evidence in clinical practice. Barrie was clearly a clinician who was well indoctrinated in the ways of clinical science, and his support for the work of James *et al*, and his appreciation of the need for basic physiological knowledge was evident in his concluding paragraph:

> Dr James and his colleagues are to be commended for devoting attention to the question of oxygen absorption for the gastrointestinal tract, and I await further details of their findings with great interest. Meanwhile, lest I face an accusation of unconstructive criticism, we should ponder deeply on the fact that even a 400g human foetus can be adequately oxygenated from the lungs.[761]

As well as being a member of the growing neonatal network, Barrie was also an example of the newer breed of clinicians who clearly embraced the move towards a more scientific and objective evaluation of clinical practice, and use of a

757 Ibid.

758 Ibid.

759 Ibid.

760 Ibid.

761 Ibid.

physiological basis to inform and direct clinical practice. Further evidence of these ties is seen in his adoption of intubation with positive pressure as the most appropriate method of resuscitating severely asphyxiated newborns, which he had been introduced to by Virginia Apgar.[762] So when he was attacking intragastric oxygen, it was not only due to the lack of objective evidence, but also as a defence of intubation and positive pressure.

Barrie's letter was soon followed in 1960 by a more substantial attack on the technique by another clinician turned physiologist with a strong belief in the importance of the scientific approach to evaluating medical practice and also the importance of basic physiology for medical research. RV Coxon was working at the University of Oxford Physiology Laboratory and was prompted to contribute to the critique of intragastric oxygen by his dismay at the lack of 'clear quantitative evidence by which to assess its efficacy'.[763] He further argued that 'a full account has not been taken of factors incidental to rather than peculiar to resuscitation by intragastric oxygen in its evaluation'.[764]

The evidence presented in his paper was collected whilst trying to develop a means of monitoring oxygen therapy in newborns. However he was careful to select data 'from experiments where other manoeuvres were not likely to interfere with the interpretation of the blood-saturation figures'.[765] The research was conducted on adult cats and puppies, which were anaesthetised, had their lungs artificially collapsed, treated with intragastric oxygen, and had blood samples taken from either the femoral artery or portal vein. Coxon reported that 'intragastric oxygen was ineffective', and that 'a very high degree of arterial saturation was maintained by intratracheal oxygen'.[766]

In his discussion Coxon, like Barrie, was critical of Åkerrén and Fürstenberg's attempts to provide physiological basis to their paper:

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762 McAdams, R. (2007). Interview with Dr Herbert Barrie, 31st January.

763 Coxon, R. V. (1960). "The effect of intragastric oxygen on the oxygenation of arterial and portal blood in hypoxic animals." *Lancet* **1**: 1315-1317.

764 Ibid. p1315

765 Ibid. p1315

> Using the data of McIver *et al*, and making some favourable assumptions, Åkerrén and Fürstenberg concluded that oxygen could be transferred across the gut to the portal blood in large enough amounts and rapidly enough to make a significant contribution to the metabolic needs of a hypoxic infant…But, although the calculation represented a laudable effort to provide a theoretical basis of Åkerrén and Fürstenberg's therapeutic claims, direct evidence of improved portal or arterial oxygenation was not obtained.[767]

Coxon further attacked the latter advocates of intragastric oxygen whom, he claimed, 'assessed their results exclusively in descriptive rather than quantitative terms'.[768]

On the contrary those opposed to intragastric oxygen felt they had provided more objective scientific evidence. Coxon argued that his own data showed that 'those [animals] which were given intragastric oxygen did not, as a group, display any consistent advantage over the control animals which were not treated or which had sufflation of room air'.[769] He further argued that 'when improvement appeared to follow intragastric insufflation, this was attributable to reflex stimulation of respiratory movements by the oesophageal tubes, or possibly by stretching of the stomach and adjacent structures, coupled with a high concentration of oxygen in the pharynx from leakage round the tubes'.[770] Again like Barrie, Coxon questioned the sequence of events used in the case reports to identify recovery, arguing that they are 'compatible with the idea that mechanical stimulation of respiratory movement is the primary effect of intragastric oxygen'.[771]

Coxon concluded by further highlighting that intragastric oxygen was not totally risk-free, and urged advocates to seek further quantitative evidence if they were to continue to use it:

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766 Ibid. p1316

767 Ibid. p1316-1317

768 Ibid. p1317

769 Ibid. p1317

770 Ibid. p1317

771 Ibid. p1317

> But the intragastric administration of oxygen is not entirely free from risk and misplaced trust in its value may deter the search for more efficacious therapeutic procedures. Hence, any quantitative information casting doubt on the value of intragastric oxygen may perhaps incite advocates to seek more definitive indications of its merits than are presently available.[772]

As has been discussed in the previous chapters, it was not only paediatricians and physiologists who had begun to take an interest in the care of the asphyxiated newborn, anaesthetists had also gained a voice in the discussions. This trend was illustrated in the next attack on intragastric oxygen, which came from the Newcastle-based anaesthetists, EA Cooper, H Smith and EA Pask.[773] They recognised that intragastric oxygen was 'widely used in Britain', but that it lacked any real physiological evidence and there had been no clinical trial adequate enough to allow 'valid assessment'.[774] They did acknowledge the difficulty of mounting such a clinical trial of the technique 'since only a small proportion of babies are in need of resuscitation and many of these cannot be saved by any means'.[775] They therefore decided to conduct a series of experiments on kittens, which allowed them to circumvent both ethical and practical obstacles.

However, even in animal experiments, the anaesthetists were aware of several difficulties with assessing the efficacy of intragastric oxygen. One of these problems concerned the fact that:

> The procedure incidentally results in filling of the oro- and naso-pharynx with oxygen. Thus any air which can come into effective contact with alveolar membrane is enriched in oxygen and apparent benefit may result from this, rather than from intestinal absorption.[776]

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772 Ibid. p1317

773 Cooper, E. A., H. Smith, et al. (1960). "On the efficiency of intragastric oxygen." *Anaesthesia* **15**(3): 211-228.

774 Ibid. p211

775 Ibid. p211

776 Ibid. p211

Furthermore, the anaesthetists agreed with Stanley James and his colleagues at Columbia, who had argued that any benefit of the technique should be attributed to the sensory stimulation of passing catheters.[777]

Considering all these factors Cooper and his colleagues had devised three sets of experiments which would ‘determine whether the introduction of oxygen into the gastro-intestinal tract result[ed] in effective transfer to the systemic circulation’ by providing evidence of: benefit measured solely in terms of length of survival; benefit assessed by measurement of oxygen content of blood; and evidence of oxygen loss from the intestinal tract.[778] The experiments were very comprehensive and objective, and the investigators considered a variety of variables which may have compromised the findings.

From the first series of experiments they found that ‘intragastric oxygen made little or no difference to the survival time of newborn kittens acutely deprived of pulmonary oxygen intake’.[779] They also attempted to resuscitate kittens after near or complete cardiac arrest, using intragastric oxygen. However, they concluded that: ‘we have never seen improvement result from this, nor have we ever been able to re-establish heart beats after arrest has taken place’.[780] Overall their findings from the first set of experiments led Cooper and his colleagues to conclude that, ‘in terms of the survival of the cardiovascular system of newborn kittens, we were unable to detect any benefit derivable from the use of intragastric oxygen’.[781]

The second series of experiments was aimed at trying to obtain evidence of an increase in the oxygen content of the blood with intragastric oxygen. Both arterial and aortic oxygen saturation were monitored with neither showing a significant

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777 Ibid. p211.
James, L. S., F. Moya, et al. (1959). "Letter to the editor: Intragastric administration of oxygen." *Lancet* **1**: 737.

778 Cooper, E. A., H. Smith, et al. (1960). "On the efficiency of intragastric oxygen." *Anaesthesia* **15**(3): 211-228.

779 Ibid. p214.

780 Ibid. p218.

781 Ibid. p218.

increase.[782] The theory that the liver consumed any oxygen which was absorbed via intragastric oxygen was also tested, and they found a detectable increase in the oxygen concentration of blood in the mesenteric vein.[783] The final series of experiments were aimed at assessing the loss of oxygen from the lumen of the isolated cat intestine during intragastric oxygen treatment, using an oxygen rich haemoglobin mixture and an oxygenated saline solution. However, Cooper *et al* concluded that:

> All the experiments in this section had shown that a major portion of the oxygen lost from the lumen of the intestine did not succeed in passing through the wall to the mesenteric circulation, presumably being used for the metabolic needs of tissues.[784]

Cooper *et al* estimated that a normal kitten requires no less that 0.30 millilitres of oxygen per minute per 100g for cardiovascular survival.[785] However, their data had shown that intragastric oxygen could not provide this, and even the oxygen that was absorbed was possibly being lost to the liver.[786] They therefore argued that intragastric oxygen 'showed no benefit' on the survival of their anoxic kittens.[787]

This attack not only illustrates the involvement of the anaesthetist in debates surrounding the care of the asphyxiated newborn, and their promotion of intubation with positive pressure insufflation. It also demonstrates the growing trend towards applying more objective and scientific methods of assessing the efficacy of clinical treatments. The anaesthetists promoted the use of these scientific research methods in clinical research, and saw the value of using animal research and basic physiology research to inform and evaluate clinical practice.

A month after Cooper *et al*'s paper was published, another letter appeared in the *Lancet*, detailing an experiment conducted by a Pennsylvanian obstetrician, Philip

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782 Ibid. p218-219.

783 Ibid. p222.

784 Ibid. p223-224.

785 Ibid. p226

786 Ibid. p227

787 Ibid. p227

K Nelson, on a 39 week old anencephalic infant.[788] Nelson reported how, due to mounting popularity of intragastric oxygen during the mid-1950s, and a lack of 'quantitative blood-oxygen determinations', in any of the clinical reports, he wanted to attempt to gather such data.[789] However, feeling an ethical dilemma over compromising the life of an infant, he decided that an anencephalic infant would be a better experimental subject, as the abnormality was 'invariably fatal within an hour or so'.[790] Such an abnormal pregnancy was detected in the wife of a resident doctor, who granted permission for the experiment.[791] As soon as the infant was born it was removed to a separate room, and a tight endotracheal tube was fitted, followed by the intragastric oxygen apparatus.[792] An umbilical catheter was fitted to monitor blood-oxygen saturation, and then the endotracheal tube was occluded to inhibit pulmonary exchange, whilst intragastric oxygen was administered at 2 litres oxygen per minute.[793] The 'serial blood samples showed a constant fall in the oxygen content until the time of death, 31 minutes after the start of the study'.[794] This single case report allowed Nelson to conclude, like Coxon and James *et al*, that 'gastrointestinal oxygenation is in all likelihood valueless'.[795]

A further and major blow to intragastric oxygen came when an editorial in the *Lancet* highlighted the controversy now surrounding its use.[796] Commenting on the rapid spread of intragastric oxygen in Britain, after Åkerrén and Fürstenberg's 1950 article, the article went on to discuss the increasing evidence, which challenged its efficacy.[797] After detailing the numerous clinical and experimental

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788 Nelson, P. K. (1960). "Letter to the editor: Intragastric oxygen." *Lancet* **2**: 317-318.

789 Ibid.

790 Ibid.

791 Ibid.

792 Ibid.

793 Ibid.

794 Ibid.

795 Ibid.

796 Fox, T. F. (1960). "Annotation: Intragastric oxygen." *Lancet* **2**: 1129-1130.

797 Ibid.

reports which suggested that intragastric oxygen was valueless, Fox stated that 'there is no comparable evidence to support the claim that it is a useful procedure'.[798] Pointing to the added dangers of the technique, which had been presented by Barrie, Fox called on the advocates of the technique to provide substantial supportive evidence to the contrary, if the technique was to continue to be employed.[799] No such supportive evidence was ever offered, and instead the final blow, which contributed to the ultimate abandonment of the technique came in 1963, when the original critics, Stanley James and colleagues, published two papers on research that they had been conducting since their 1959 letter.[800]

The Columbia group had been funded by a US Public Health grant, and their research project encompassed both animal and clinical trials. The first series of experiments were conducted on puppies with the aim of determining whether there was any evidence of oxygen transfer from the gastro-intestinal tract to the systemic blood in the immediate neonatal period when administering intragastric oxygen.[801] The newborn puppies were given a respiratory inhibitor, some had their tracheas tied and intragastric oxygen tubes inserted, with a catheter in either their aorta or portal vein via the umbilical cord.[802] Intragastric oxygen was administered at ½ to 1 litre per minute, and 'after varying periods this was stopped and the lungs were expanded artificially by the application of intermittent positive pressure', whilst some of the puppies had their trachea occluded and were continuously given intragastric oxygen.[803] In those puppies given only intragastric oxygen, with occluded trachea, they found 'no evidence of oxygen absorption from the stomach or gut as judged by the oxygen saturation of the portal vein or aortic blood'.[804] In

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798 Ibid.

799 Ibid.

800 James, L. S., V. Apgar, et al. (1963). "Intragastric oxygen and resuscitation of the newborn." *Acta Paediatrica* **52**: 245-251,
James, L. S., V. Apgar, et al. (1963). "Intragastric oxygen: Experimental observations in newborn puppies." *Acta Paediatrica* **52**: 241-244.

801 James, L. S., V. Apgar, et al. (1963). "Intragastric oxygen: Experimental observations in newborn puppies." *Acta Paediatrica* **52**: 241-244.

802 Ibid. p241

803 Ibid. p241

804 Ibid. p242

contrast they reported a rapid rise in oxygen levels when the lungs were expanded with artificial ventilation.[805] The Columbia group concluded that:

> The use of intragastric oxygen was completely ineffective as a resuscitation procedure, even though the oxygen requirements were minimized by paralysing the animals, and the ductus venosus, foramen ovale and ductus arteriosus were patent.[806]

The second series of experiments, which were published in the same issue of *Acta Paediatrica*, concerned a study of 29 clinical cases.[807] These studies were 'undertaken in an effort to obtain quantitative evidence as to the effectiveness of the procedure in the human infant'.[808] Some of the infants were fitted with both an endotracheal tube and intragastric oxygen tubes, the endotracheal tube was occluded and intragastric oxygen was given, whilst blood samples were taken. Controls were given either intragastric oxygen without occlusion of the trachea or intragastric nitrous oxide.

They found that 'infants who were well oxygenated when the lungs were ventilated with oxygen became severely hypoxic when the endotracheal tube was occluded and intragastric oxygen was substituted for pulmonary ventilation'.[809] Those cases which had breathed spontaneously and were given additional gastro-intestinal oxygen showed 'no rise in oxygen levels'.[810] The Columbia group therefore argued that:

> These studies have shown that when the absorption of oxygen from the lungs is pathologically impaired, or prevented by occlusion of an endotracheal tube, absorption from the gastro-intestinal tract is

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805 Ibid. p242

806 Ibid. p244

807 James, L. S., V. Apgar, et al. (1963). "Intragastric oxygen and resuscitation of the newborn." *Acta Paediatrica* **52**: 245-251.

808 Ibid. p245

809 Ibid. p248

810 Ibid. p248

> negligible...the gastrointestinal route therefore cannot be used as an alternative to the lungs for oxygenation of the newborn.[811]

The Columbia group then continued to ensure there was no doubt left over the ineffectiveness intragastric oxygen, by discussing why it had been mistakenly viewed as valuable and also the inherent dangers associated with it. This in many ways undermined the evidence which had been provided in support of the technique. James *et al* argued that beneficial effects of intragastric oxygen could be caused by 'regurgitation of 100% oxygen into the pharynx from where it could diffuse into the lungs'; or the double catheter could act as a 'pharyngeal airway', holding the tongue forward and maintaining an airway for oxygen administration to the pharynx; chemo-receptors may respond to the severe anoxia and the infant would begin spontaneous respirations independent of any resuscitative efforts, and therefore this would always make it 'difficult to evaluate' any resuscitative procedure 'in the absence of controlled observations'.[812] These arguments were further backed-up by suggestions that intragastric oxygen may 'reduce ventilatory movements by pressure on the diaphragm', or may rupture the stomach.[813] However James *et al* feared the worst danger was 'that it lulls the nurse or clinician into a false sense of security and prevents him from thinking of or applying effective ventilation'.[814]

This was a very damning and compelling paper, which sealed the lid of the coffin of intragastric oxygen, whilst simultaneously boosting the position of positive pressure ventilation. It was clear that the Columbia group, who were leading advocates of positive pressure ventilation with intubation, felt threatened by the popularity of intragastric oxygen. Their closing remarks illustrate the dual role of the paper when they stated that intragastric oxygen:

> … is not a benign procedure and carries definite dangers … It cannot be considered of any value for resuscitation, nor as an additional source of oxygen for the sick infant. The only effective way to resuscitate a

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811 Ibid. p249

812 Ibid. p250

813 Ibid. p250

814 Ibid. p250

> newborn infant is by pulmonary ventilation either through the infant's own efforts, or by the application of intermittent positive pressure.[815]

It is evident that intragastric oxygen gained a rapid rise to popularity mainly due to its simplicity and accessibility to both clinicians and other medical staff, such as nurses and midwives, who may have been faced with an asphyxiated infant. During the 1950s, concerns over high infant mortality and specifically neonatal mortality, were becoming paramount in both Britain and America, which has been discussed in previous chapters. Clinicians, frustrated with their apparent inability to help asphyxiated newborns, were eager to adopt any measure which appeared to be effective. Intragastric oxygen emerged, during the early 1950s, at a time when the treatment of the asphyxiated newborn was varied and there was no consensus on the most appropriate and effective technique. Clinicians, such as Åkerrén and Fürstenberg, and Waller and Morris, attempted to embrace the increasingly scientifically-based medicine that was emerging. However, their claims of providing sound scientific evidence for their novel resuscitative technique were met with much criticism from physiologists and the new breed of clinician-scientists which made up the neonatal network.

During the 1950s the treatment of each case of asphyxia neonatorum was still dependent on the preferences of individual hospitals, doctors, or even midwives. However towards the end of the decade and through to the mid-1960s a consensus on how to treat the asphyxiated newborn was beginning to emerge, in part due to growing amount of physiological evidence and clinical research, linked to a move towards a more scientific and objective approach to assessing and evaluating clinical practice. Another important factor in this growing consensus was the formation of the national and international networks of like-minded clinicians, with a particular interest in the neonate, as described in the previous chapter. This network of individuals was able to push for the widespread adoption of positive pressure ventilation via intubation as the most effective treatment of asphyxia neonatorum. The growing influence of the neonatal network became increasingly apparent during the 1960s when another resuscitative technique,

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815 Ibid. p250

hyperbaric oxygen, was championed for newborn resuscitation. This will be discussed in the next chapter.

Chapter 7

The Hyperbaric Oxygen Controversy

Hyperbaric oxygen and the resuscitation of the asphyxiated newborn

By the early 1960s there did appear to be some general agreement on the subject of newborn resuscitation concerning the initial steps to be taken when presented with an asphyxiated newborn. The majority of British doctors agreed that the infant's airways should be cleared immediately by suctioning the naso-pharynx and then oxygen should be administered using a face-mask. However, when these initial conservative steps failed there was a divergence of opinion regarding the next steps to be taken. As has already been discussed, members of the neonatal network had formed a consensus by the early 1960s that the most effective step was to intubate the baby and apply positive pressure ventilation. However the neonatal network was a small and elite group of mainly academic paediatricians, and the majority of British doctors concerned with care of the newborn were not members. Amongst the non-network clinicians there was no general consensus on the best resuscitative treatment and many felt apprehensive about using intubation, fearing the possibility of barotrauma due to the use of positive pressure inflation. As has already been mentioned, techniques such as intragastric oxygen were still used during the early 1960s, but some doctors felt that no intervention was necessary, and argued that if an infant 'wanted to breathe' it would do so regardless of medical intervention. James Holmes Hutchison, Professor of Child Health at Glasgow University, fell within this last group of clinicians. He shared the concerns over the dangers of intubation and positive pressure methods and when he proposed his novel application of hyperbaric oxygen for asphyxia neonatorum in 1963 he felt he was addressing many of these concerns.

James Holmes Hutchison, born in Burma in 1912, moved to Glasgow at the age of eight, and after his schooling, he attended the University of Glasgow obtaining his MB ChB in 1934. As an undergraduate he developed an interest in child health.[816]

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816 Robertson, E. (1972). *The Yorkhill Story. The history of the Royal Hospital for Sick Children Glasgow*. Glasgow, Robert MacLehose & Co. Ltd.

The majority of his postgraduate medical training was based in Glasgow, working as both a houseman and then a dispensary clinician at the Royal Hospital for Sick Children, Yorkhill, although he did spend a short spell at St Luke's Hospital, Bradford.[817] He served in the RAMC during the Second World War and on his return to Glasgow he continued his paediatric training at Yorkhill and the Glasgow Royal Maternity Hospital, and established a large private practice. Hutchison built up a reputation as an excellent clinician but received no formal training in clinical science or physiology and conducted comparatively little research. Within British paediatric circles Hutchison was greatly respected and within Scottish medico-political arenas he became an important figure, sitting on many Health Services and Hospital Committees and Boards. However his accelerated appointment to the Leonard Gow Lecturship in 1947, and his subsequent rise to Samson Gemmell Professor of Child Health in 1961, came as a surprise to some of his contemporaries, as Professors were expected to have a large research portfolio.[818]

If Hutchison's early career is compared with some of the prominent British members of the neonatal network many striking differences can be found. First Hutchison spent the majority of his early career in Glasgow, never training at any of the leading neonatal research units of the post-war period, such as St Mary's or UCH in London. Unlike many of the members of the neonatal network, who spent at least a year in the USA or in a British physiology laboratory training in basic animal physiological research, Hutchison had been hospital-based. His major research interests had been a study of goitre amongst a family of travellers during the early 1950s.[819] Hutchison considered himself a general paediatrician, and resisted calls for specialization. This belief was evidenced in his refusal to join the fledgling Neonatal Society in 1959 as he did not consider himself a 'neonatologist'.[820] Although Hutchison became Professor of an academic

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817 [Anon] (1989). "Hutchison, James Holmes." *Munks Roll* **8**: 239-240.

818 McAdams, R. (2005). Interview with Professor Dan Young, November.

819 McGirr, E. M. and J. H. Hutchison (1953b). "Radioactive-iodine studies in non-endemic goitrous cretinism." *Lancet* **2**: 403,
Hutchison, J. H. and E. M. McGirr (1954). "Hypothyroidism as an inborn error of metabolism." *Journal of Clinical Endocrinology & Metabolism* **14**: 869-886,
McGirr, E. M. and J. H. Hutchison (1955). "Dysgenesis of the thyroid gland as a cause of cretinism and juvenile myxedema." *Journal of Clinical Endocrinology & Metabolism* **15**: 668-679.

820 McCance, R. Sa/nns/f.3: 'the foundation and early years of the neonatal society'. *The Neonatal Society Archive [SA/NNS]. Archives and Manuscripts, Wellcome Library.* London.

department, up until 1961 he had devoted a fair amount of his time to his large private practice. As the hyperbaric oxygen controversy is analysed it will be important to consider the role that the neonatal network played in how Hutchison was perceived, and how his position within neonatal research in particular, and in paediatrics more generally, in Britain affected the reaction to hyperbaric oxygen.

In the mid-twentieth century, to quote Sheridan,:

> Intensification of research into hyperbaric physiology and medicine was prompted by the divers and aviators who probed the bounds of survivable pressures during military manoeuvres in World War II. This research was necessary to support high-altitude flight and diving that was required of military personnel during the war effort, and a strong interest in hyperbaric and hypobaric physiology has remained an important part of military medicine.[821]

In the post-war years this interest in the potential use of hyperbaric oxygen continued, as clinicians and physiologists looked at its possible use in the management of surgical and medical problems, marked by the publication of Churchill-Davidson’s 1955 paper on the value of hyperbaric oxygenation as an aid to radiotherapy.[822] One of the leaders of the field was the Dutch surgeon, Professor I Boerema, who published the highly influential article ‘Life without Blood’ in the *Journal of Cardiovascular Surgery* in 1960.[823] This article prompted an interest in the use of hyperbaric oxygen for ventilation. Using a naval hyperbaric chamber, Boerema argued that under high pressure enough oxygen could be dissolved in the blood plasma to sustain tissues without the need for haemoglobin.

Boerema continued to investigate the use of hyperbaric oxygen in surgery, and built a large hyperbaric operating theatre. Some of his early work involved the use of hyperbaric therapy whilst performing palliative surgery on severely cyanotic newborns.[824] In Glasgow the Professor of Surgery at the Western Infirmary,

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821 Sheridan, R. (1999). "Hyperbaric oxygen treatment: A brief overview of a controversial topic." *The Journal of Trauma: Injury, Infection, and Critical Care* **47**(2): 426-435.

822 Rendell-Baker, L. and J. Jacobson (1999). "Hyperbaric oxygenation." *International Anaesthesiology Clinics* **37**(1): 137-167.

823 Boerema, I. (1960). "Life without blood." *Journal of Cardiovascular Surgery* **1**: 133-146.

824 Rendell-Baker, L. and J. Jacobson (1999). "Hyperbaric oxygenation." *International Anaesthesiology Clinics* **37**(1): 137-167. p148.

Charles Illingworth, also became interested in the surgical use of hyperbaric oxygen, and installed his own hyperbaric chamber in 1960.[825] The work of both Boerema and Illingworth sparked widespread interest in the possible benefits of hyperbaric oxygen during the early 1960s, and it was soon seen as a panacea for a number of ailments. It was through Illingworth's work in Glasgow that Hutchison first became interested in the therapy and his initial studies were conducted in Illingworth's hyperbaric chamber in the Western Infirmary in collaboration with some of Illingworth's staff.[826]

Initially Hutchison believed that hyperbaric oxygen could prove a valuable treatment for the pulmonary syndrome of the newborn. However after investigation he found that it was ineffective for treating the hypoxia associated with the disease.[827] Hutchison re-directed his research towards the treatment of asphyxia neonatorum in 1963, but he was not the first to apply hyperbaric oxygen to the respiratory problems of the newborn.

After Vickers Medical Ltd first described their adult hyperbaric chamber in the *Lancet* in 1960, a Blackburn paediatrician, PD Moss, contacted the firm directly about the possible use of the treatment for respiratory distress syndrome in the neonate.[828] In 1961 Vicker's built an infant sized chamber, which they gave to Moss for a small-scale trial of the treatment of a variety of respiratory conditions of neonates, and he reported his findings at the 33rd Annual meeting of the British Paediatric Association in April 1962. He reported that he had treated twenty cases with success in two cases of asphyxia neonatorum and three cases of respiratory distress.[829] Although Moss appeared to have continued to investigate the use of the therapy, his research was inhibited by the relatively small size of his obstetrical unit in Blackburn, and he never published a substantial series of cases.

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825 Hutchison JH, K. M., McPhail FM, Douglas TA, Smith G, Norman JN & Bates EH (1962). "Studies in the treatment of the pulmonary syndrome of the newborn." *The Lancet* **2**: 465-469.

826 Ibid.

827 Ibid. Pulmonary syndrome was one of several terms used to described respiratory distress syndrome during the early 1960s, the other popular term was hyaline membrane disease.

828 Moss, P. (1963). "Hyperbaric oxygen in the resuscitation of the newborn." *Lancet* **2**: 1124.

829 Ibid.

Hutchison began collaborating with the engineering firm Vickers Medical Ltd, who also provided Glasgow with an infant sized hyperbaric chamber. The hyperbaric chamber, which can be seen in figure 15, consisted of a closed Perspex cylinder, within which the infant was placed. The pressure within the chamber could then be raised as a steady stream of oxygen was pumped into the cylinder. By increasing the pressure within the chamber, the oxygen concentration within it would be increased. Hutchison believed that the greater oxygen concentration created a larger oxygen diffusion gradient between the infant and its environment, which led to an increase of oxygen diffusion through the infant's skin and upper respiratory surfaces, into the blood, therefore supplying vital oxygen to the baby. The Vickers Medical researcher, Kenneth Williams, who worked along with Hutchison, had conducted some initial animal research on fetal rats, showing oxygen absorption through the skin, which appeared to support the use of the treatment for newborn resuscitation.[830]

Figure 15. Infant size hyperbaric oxygen chamber. Image taken from Hutchison et al (1964) 'Hyperbaric oxygen in the resuscitation of the newborn', the *Lancet*, p691-692.

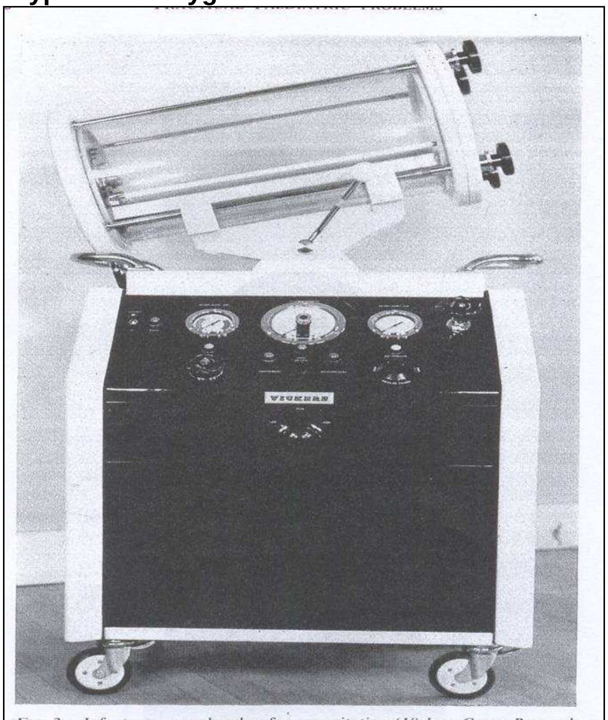

FIG. 3.—Infant pressure chamber for resuscitation (*Vickers Group Research Establishment*).

In 1963 Hutchison's group, which included Williams of Vickers and the paediatrician Margaret Kerr, who had a special interest in the newborn, published the results of their uncontrolled trial of sixty-five infants with asphyxia neonatorum treated with hyperbaric oxygen. It was clear that they thought that hyperbaric

830 Hutchison, J. H., M. M. Kerr, et al. (1963). "Hyperbaric oxygen in the resuscitation of the newborn." *Lancet* **1**: 1019-1022.

oxygen was a major advance in neonatal care in light of the problems highlighted in the 1958 National Birthday Trust's Perinatal Mortality Survey, and also the continued perceived dangers associated with intubation and positive pressure methods.[831]

Hutchison claimed that this was a novel application of hyperbaric oxygen. In surgical cases, reported by Boerema and Illingworth, the aim was to increase the amount of oxygen dissolved in the blood plasma. However with asphyxiated newborns, the aim was to increase the reduced oxygen saturation of the haemoglobin.[832] It was applied after the standard conservative methods had failed, which included clearing of the airways and administering oxygen with a face-mask. The Glasgow group commented that:

> The effects were usually dramatic. Within a few minutes the cyanosis and pallor of asphyxia pallida gave way to a gratifying pink, and the heart-rate increased. Intermittent gasps were followed by true respiratory movements. Limpness was replaced by kicking and often crying. The picture of the apparently dead infant trying to 'fight his way' out of the chamber after a few minutes were sometimes most impressive.[833]

This was quite a dramatic description in support of the technique, and the Glasgow team were convinced of its efficacy. Their clinical results showed a 54 per cent survival rate.

Those infants which died underwent pathological examination, and the group were able to conclude that death in twelve of those which died after six hours 'could not have been attributed to hyperbaric oxygen'.[834] Of those which died under six hours, it was found that 'in all but 1 infant there was an adequate explanation of the failure'.[835] This allowed the Glasgow group to conclude that hyperbaric oxygen was:

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831 Ibid. p1019.

832 Ibid. p1020.

833 Ibid. p1020.

834 Ibid. p1022.

835 Ibid. p1022.

> an effective method of making oxygen quickly available to the anoxic tissues of the apneic newborn infant. It has the advantage of speed, and the apparatus can be operated after only a short course of instruction.[836]

Aware that their study might come under attack for not being a controlled trial Hutchison *et al* argued in justification of their research that:

> Apnoea neonatorum is not an emergency in which a controlled trial would be permissible, but it is our firm impression that hyperbaric oxygen is the most effective method of resuscitation yet devised for the severely asphyxiated newborn infant.[837]

This was a very provocative statement, which quickly irritated members of the neonatal network who felt that the study lacked any scientific grounding and that the research findings were misleading. It also stimulated interest amongst those clinicians who shared Hutchison's apprehension of using intubation and positive pressure methods, and were convinced by the dramatic descriptions of recovery of individual cases. The paper caused a heated debate within the British neonatal network, with prominent paediatricians and physiologists openly questioning both the group's research methods and the efficacy of hyperbaric oxygen.

Reactions to Hutchison *et al'*s paper

One of the first to comment on Hutchison's paper was the paediatrician, Dr Herbert Barrie, who was a senior registrar at St Thomas' Hospital, London. As has already been mentioned, Barrie had spent a year working alongside Charles Davenport Cook in Boston in 1958. During his time in the USA he had trained in clinical science and developed an interest in the resuscitation of the newborn. Barrie was a member of the neonatal network which was described in chapter 5. He returned from Boston a strong advocate of intubation with positive pressure ventilation for the resuscitation of the asphyxiated newborn, publishing several articles during the late 1950s and early 1960s.[838] Emerging as a major supporter of

836 Ibid. p1022.

837 Ibid. p1022.

838 Barrie, H. (1959). "Letter to the editor: Intragastric administration of oxygen." *Lancet* **1**: 884-885.
Barrie, H. and R. Bonham-Carter (1959). "Correspondence: Respiratory difficulties at birth." *BMJ*: 1183-1184.
Cook, C., H. Barrie, et al. (1960). "Respiration and respiratory problems of the newborn infant."

intubation and positive pressure ventilation, he clearly had a vested interest in its success and uptake. This was evident in his critique of Hutchison's research and hyperbaric oxygen as a technique, which can be viewed as a defence of his own research and practice.

Although Barrie's letter began by emphasising that Hutchison and his team were 'widely respected', it soon turned into a harsh critique of almost every aspect of the paper.[839] His attack was arranged under four headings: method; mortality; analysis of fatal cases; and specific statements made in the paper. Barrie argued that Hutchison's research was unscientific, even suggesting that he had tried to disguise his lack of 'objective' and 'scientific' measurements by using the term 'electro-physiological monitoring' to describe basic clinical observations.[840] This was an attack on the Glasgow team's abilities as clinical scientists. Barrie further claimed that Hutchison had made several unsubstantiated statements in the paper, including his use of a 46 per cent mortality figure to support their claim that hyperbaric oxygen was 'the most effective method of resuscitation yet devised', and his claim that there was 'increasing evidence' of a significant cutaneous oxygen absorption.[841]

Barrie repeatedly cast doubt on Hutchison's clinical skills, suggesting that he had failed correctly to assess Apgar scores, and had misdiagnosed deaths due to stillbirth and meconium aspiration.[842] He even insinuated negligence, by suggesting that these deaths were due to a failure to keep the airways clear and to intubate the infants.[843] Also quite damning was Barrie's claim that hyperbaric oxygen would echo the fate of two well-known failed resuscitative techniques, intragastric oxygen and the Bloxsom Air Lock. As has been previously discussed,

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Advances in Pediatrics **11**: 11-80.
Barrie, H. (1962). "The apgar evaluation of the newborn infant." *Developmental Medicine and Child Neurology* **4**(2): 128-132.
Barrie, H. (1962b). "Respiratory stimulants in the newborn." *Lancet* **2**: 742-746.
Barrie, H. (1963). "Resuscitation of the newborn." *Lancet* **2**: 650-655.

839 Barrie, H. (1963). "Hyperbaric oxygen in resuscitation of the newborn." *Lancet* **2**: 1223-1224.

840 Ibid. p1223.

841 Ibid. p1223-1224.

842 Ibid. p1223-1224.

843 Ibid. p1223-1224.

both of these techniques had gained rapid and widespread popularity during the 1950s in Britain and America respectively. By the 1960s in Britain, intragastric oxygen was regarded as an embarrassing and dangerous misadventure in the care of the asphyxiated newborn. Both techniques had been cited by members of the neonatal network as examples of how a lack of scientific method, knowledge and objectivity, could lead to the misguided use of an ineffective technique. Comparing hyperbaric oxygen to this failed technique was a very damning critique, which implied that both it and Hutchison's research were unscientific.

Barrie was not only defending the ethos of the neonatal network, which supported the need for more objective and scientific methods of assessing clinical practice, as well as valuing the importance of animal research and basic physiology for clinical science. He was also defending his own practice at St Thomas', where he advocated the use of intubation and positive pressure ventilation. Barrie's letter was an extremely detailed and damning critique, and yet it was also quite defensive. This defensive tone was clear in the concluding paragraph:

> The history of neonatal resuscitation is a long uphill struggle of pioneers in intermittent positive-pressure inflation of the lungs in the face of such nugatory diversions as intragastric oxygen, the Bloxsom air lock, and even 'masterly inactivity'. Only the past few years have seen its acceptance as the most effective method of neonatal resuscitation, and, as such, it is being increasingly practiced in the delivery room…Having come so far, we must learn from these years of scientific endeavour to be justly critical of any step which might be retrogressive.[844]

Barrie's ruthless critique of Hutchison's research in such a public forum warranted an immediate response from the Glasgow team, which was published two weeks later in the *Lancet*.[845] In their letter the Glasgow team addressed each of the individual points raised by Barrie. They defended their use of 'careful clinical observations', and even attacked Barrie's 1963 paper, stating that:

> It is perhaps permissible to point out that Dr Barrie's own paper on the value of intermittent positive-pressure inflation rests entirely upon

[844] Ibid. p1224.

[845] Hutchison, J., M. Kerr, et al. (1963). "Hyperbaric oxygen in resuscitation of the newborn." *Lancet* **2**: 1334-1335.

> clinical observations, and indeed we know of no work showing the effect of this method upon the arterial oxygen saturation in the viable newborn infant.[846]

Hutchison further argued that it was ‘regrettable’ that they did not provide arterial oxygen estimations in their trial, but it was ‘impossible’ to do such tests when the infant was under pressure in the chamber.[847] Hutchison agreed with Barrie that more animal research would be useful, and was at pains to emphasize that they believed that even in the newborn the majority of oxygen diffuses through the respiratory tract. Hutchison offered the clarification that:

> We did not claim that in hyperbaric oxygen most of the diffusion was through the skin. We suspect that it takes place mostly through the mucous membranes of the respiratory tract, and we have not found airway obstruction to occur in the pressure chamber.[848]

Hutchison further argued that he had not intended to question the therapeutic value of intubation and intermittent positive-pressure. However, he stated that the technique’s popularity did ‘not mean it is the best method’ available.[849] Hutchison also sarcastically commented:

> We would congratulate Dr Barrie on his ability to expand the lungs of every apnoeic newborn infant. In common with others we have been unable to achieve this measure of success with intermittent-positive pressure inflation.[850]

Clearly the Glasgow team could see the value of intubation and positive pressure methods, yet they felt that hyperbaric oxygen was a legitimate alternative which was simpler to apply. The Glasgow team’s response was both defensive and laced

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846 Ibid. As was mentioned in Chapter 5 Barrie had published a paper in 1963 which described in detail the use of intubation and positive pressure ventilation for the treatment of asphyxia neonatorum.
Barrie, H. (1963). "Resuscitation of the newborn." *Lancet* **2**: 650-655.

847 Hutchison, J., M. Kerr, et al. (1963). "Hyperbaric oxygen in resuscitation of the newborn." *Lancet* **2**: 1334-1335. p1334.

848 Ibid. p1334.

849 Ibid. p1334.

850 Ibid. p1334.

with sarcasm and critiques of Barrie's own practice. In some ways the heated exchange in the pages of the *Lancet* was a very public mud-slinging competition, which escalated further when another prominent member of the neonatal network, Professor Peter Tizard, entered the debate.

As has already been mentioned Peter Tizard had taken an early interest in the newborn, and had spent time training in clinical science at both Boston with Cook and also in Oxford with Geoffrey Dawes. Tizard had moved to the Nuffield Neonatal Research Unit at Hammersmith Hospital, London, in 1954 and he became a leading authority on neonatal care by the mid-1960s in Britain. He was also a founding member of the Neonatal Society. So his contribution to the hyperbaric oxygen controversy represented an attack from a leading member of the neonatal network.

With his close links to Dawes' unit in Oxford and his belief that animal research could be used to fill in many of the gaps in newborn physiology, Tizard was well aware of the current discoveries of the researchers at the Puerto Rican research labs, headed by William Windle. As has been described in chapter 5, the Puerto Rican researchers had defined two stages of asphyxia in the newborn, primary and secondary apnoea, which they believed were the key to assessing the condition of the asphyxiated newborn and also for determining the treatment which should be given.[851] So when Tizard and his Senior Lecturer John Davis, who as has already been mentioned was also a key member of the neonatal network, wrote to the *Lancet* in response to Hutchison's paper on 18th January 1964, their major criticism was that Hutchison's team had failed to clearly identify the stage of apnoea of their clinical cases.[852]

Tizard and Davis explained that infants in primary apnoea were more likely to begin spontaneous respirations regardless of medical intervention, and that simple stimulatory measures such as suctioning the naso-pharynx and administering oxygen via a face-mask would be sufficient to help the baby initiate respiration. However, infants in secondary apnoea required immediate and active

851 See chapter 5 for discussion of the research findings of the Puerto Rican group.

852 Davis, J. A. and J. P. M. Tizard (1964). "Hyperbaric oxygen in resuscitation of the newborn." *Lancet* **1**: 166.

resuscitation. They believed that the majority of asphyxiated newborns were actually in the primary apnoea or the pre-terminal phase, where simple methods would suffice, and argued that a clear understanding on the different stages of asphyxia was the key to assessing methods of resuscitation.[853]

The Hammersmith clinicians patronisingly commented that Hutchison's group seemed to have placed no importance on the sequence of events in asphyxia and recovery, suggesting a lack of familiarity with the animal research.[854] They further argued that the Glasgow group's case reports suggested that some of their cases were in fact in primary apnoea, which meant that artificial ventilation was not required, and that these cases were in fact misleading as they provided deceptively positive results.[855] Tizard and Davis were effectively attacking Hutchison's skills as a clinician, suggesting he lacked diagnostic acumen in this area.

Like Barrie the Hammersmith paediatricians compared hyperbaric oxygen to the 'failed' resuscitative technique intragastric oxygen, and claimed that Hutchison's data were analogous to that used to support intragastric oxygen. Hutchison's group and those who supported intragastric oxygen claimed that their respective techniques first oxygenated the blood of newborns, which in turn stimulated the initiation of gasping. Tizard and Davis therefore asked Hutchison's group:

> … how many of their 35 surviving babies responded to their treatment by first becoming pink and then breathing? It is a matter of importance. Most of the successes attributed to intragastric oxygen were probably due to non-specific stimuli leading first to inflation of the lungs by gasping and then to oxygenation by diffusion. This form of treatment would have been discredited sooner had its advocates distinguished between these different sequences of events.[856]

853 Ibid.

854 Ibid.

855 Ibid.

856 Ibid.

They damningly concluded that the use of hyperbaric oxygen ‘seems to be a retrograde step in light of what is known about resuscitation in both animals and human beings’.[857]

Hutchison and his associates were quick to respond to this attack. Clearly insulted by Tizard and Davis’s blatant challenge to their clinical skills, their response was very abrupt in tone and lacked the usual professional platitudes. They began by giving more detailed information on the sequence of events in each of their cases, referring to spontaneous gasps, colour improvements and time of respiration commencing or failing to commence.[858] This was clearly meant to justify their analysis of their results and they again stated their belief that:

> We have no doubt that this method of treatment [hyperbaric oxygen] is effective in achieving the prime object of any method of resuscitation – namely, to introduce oxygen into the circulating blood.[859]

The Glasgow team again challenged the use of intubation and positive pressure methods. Although they conceded that it appeared to be ‘the most rational method’, they argued that ‘some experienced paediatric pathologists remain unconvinced that it does, in fact, bring about expansion of the lungs, without which it cannot achieve much at normal atmosphere’.[860] They also reiterated their contention that intubation required much more skill than hyperbaric oxygen, which was equally, if not more effective. Hutchison and his colleagues concluded that they were ‘at a loss to see any justification for the suggestion by Dr Davis and Dr Tizard that its use is a retrograde step’.[861] It was obvious that Hutchison and his colleagues were determined to defend their belief in the efficacy of hyperbaric oxygen, and felt totally justified in advocating its use.

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857 Ibid.

858 Hutchison, J. H., M. M. Kerr, et al. (1964a). "Hyperbaric oxygen in the resuscitation of the newborn." *Lancet* **1**: 225.

859 Ibid.

860 Ibid.

861 Ibid.

Ministry of Health and Medical Research Council become concerned about the controversy

With the growing interest in the possibilities of hyperbaric oxygen therapy as a panacea for a variety of medical problems during the early 1960s, the Ministry of Health (MoH) was receiving an increasing stream of requests for funding for new hyperbaric facilities. As a result Dr Catherine Dennis was asked to gather information on this new therapy and its various applications.[862] Dennis produced a memorandum, which surveyed the current research being undertaken within Britain, identifying Glasgow as the major centre of research, and also reported on the international situation, having attended two international hyperbaric oxygen conferences, in Amsterdam and New York. She concluded that:

> With regard to the provision of facilities for hyperbaric oxygen therapy [the situation] was tending to get out of hand, and that there was a great need for more basic physiological work and for controlled studies to evaluate the correct place of this form of treatment.[863]

Dennis hoped that the Medical Research Council (MRC) would sponsor the basic research, much as the US National Institute of Health was doing.[864] Dr Herrald, who worked for the MRC, agreed with Dennis stating that:

> It would seem that hyperbaric oxygen therapy was still in the stage of research and evaluation, but that the NHS were already involved since the treatment required the provision of special facilities and ancillary services. The type of work was beyond the stage of pure research being concerned with the trying out of a new idea, but was clearly far from ready for routine clinical use.[865]

George Godber, Chief Medical Officer of the MoH, wrote to the Secretary of the MRC, Sir Harold Himsworth, regarding the matter in December 1963. Aware of the fact that the MRC and the Scottish research funds were already supporting various

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862 Godber, G. (1963). Fd 23/869 item 3: Letter to sir harold himsworth, secretary of the m.R.C., from george godber, chief medical officer, 11th dec. *MRC Archives, National Archives*. London.

863 Dennis, C. (1963). Fd 23/869 item 2: Note dated 28th november 1963. *MRC Archives, National Archives*. London.

864 Ibid.

865 Ibid.

hyperbaric oxygen schemes, such as Illingworth's research in Glasgow, and that international conferences were also being organised, Godber asked Himsworth about the possibility of a joint conference, between the MoH and MRC, to assess the therapy.[866] Godber's concerns appeared to have been two-fold: he feared that 'a great deal of money could be wasted' if research was not properly directed; and he also feared that Britain could 'still lag behind' internationally in hyperbaric research.[867]

As Godber detailed the current situation in Britain, there was a sense that hyperbaric oxygen could be the 'next big thing'. However there was also a feeling that at this stage the research underway was disorganised and unfocused. Godber was also concerned because: 'It seems that there is at present a tendency for people to want to establish hyperbaric oxygen units rather more rapidly than knowledge advances'.[868] He therefore hoped that the proposed conference would review the 'existing knowledge of the basic physiological and clinical application of hyperbaric oxygen' and would 'advise the Council on the further research necessary to assess whether or not this form of treatment is suitable for more widespread use'.[869]

This view was shared by the MRC, with Herrald commenting to Sir Harold Himsworth that they must:

> … try to introduce a national plan for the co-ordination and consolidation of effort in this field; failing this, there will inevitably be a great deal of mis-spent effort and waste of money probably leading in the end to a confused situation.[870]

866 Godber, G. (1963). Fd 23/869 item 3: Letter to sir harold himsworth, secretary of the m.R.C., from george godber, chief medical officer, 11th dec. *MRC Archives, National Archives*. London.

867 Ibid.

868 Godber, G. (1963). Fd 23/869: Typed noted from george godber to dr herrald, 3rd dec. *MRC Archives, National Archives*. London.

869 Ibid.

870 Herrald, J. (1963). Fd 23/869: Handwritten note in red pen from dr j.R. Herrald to sir harold himsworth, 15th dec. *MRC Archives, National Archives*. London.

It would seem that they were hoping somehow to harmonise opinions and focus research. However Himsworth was also unsure of the merits of the therapy. In a letter to Sir Lindor Brown, Himsworth commented:

> We are at the beautiful stage where a promising bandwagon has rolled out of the factory and many people are anxious to jump on it. To make sure we channel the available support to the best places is thus one of our problems.[871]

From early 1964 the MRC went about reviewing the status of hyperbaric research and therapy in the UK and invited the key researchers and other experts to the conference which was organised for the 23rd April 1964.[872] Charles Illingworth, owing to his unrivalled experience and knowledge of the field, was asked to provide a general introduction to the conference.[873] Thereafter the papers covered three themes: basic physiological problems; applied physiological problems; and clinical applications of hyperbaric oxygen therapy.

In light of the controversy surrounding Hutchison's *Lancet* paper on hyperbaric oxygen and the resuscitation of the newborn, this topic was highlighted as one of the key areas to be addressed at the conference.[874] The topic featured prominently during the 1964 conference, where Hutchison and Geoffrey Dawes presented papers which highlighted their conflicting opinions of the therapy.[875] As has already been discussed in previous chapters, Dawes was a key member of the international neonatal network and by the 1960s was a world-recognized expert in

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871 Himsworth, H. (1964). Fd 23/869 item 138: Typed letter from sir harold himsworth to sir lindor brown, oxford university laboratory of physiology, 31st march. *MRC Archives, National Archives*. London.

872 (1963-1964). Fd 23/869: File on the conference on the use of hyperbaric oxygen therapy, held 23rd april 1964. *MRC Archives, National Archives.* London.

873 Ibid.

874 Dennis, C. (1964). Fd 23/869 item 51: Airmail letter from catherine dennis to dr herrald, 17th feb. *MRC Archives, National Archives*. London.

875 (1964). Fd 23/870: Chairman's notes sent to hedley atkins, 17th april 1964, 'conference on the use of hyperbaric oxygen therapy: Chairman's notes'. *MRC Archives, National Archives*. London.

the field. He emerged as major critic of hyperbaric oxygen for newborn resuscitation.

Other attendees who opposed Hutchison's research included the obstetrician Professor Kenneth Donald of Edinburgh. Donald wrote to Dr Herrald in February 1964, commenting:

> As you may know, I feel fairly strongly on this matter in so far as a number of people are pressing for large expenditure before a thorough review of the objective value of this form of treatment and the organisation of precise and appropriate animal experiments … I feel that a more balanced and cautious attitude is necessary.[876]

Peter Tizard, identified as someone who did 'not share the general enthusiasm for the use of hyperbaric oxygen therapy in babies', had also been asked to attend the conference.[877]

During his introductory comments, Illingworth stated that:

> … he fully accepted that it would be most unfortunate if the whole technique of hyperbaric oxygen therapy were to fall into disrepute owing to over-enthusiasm at the outset. On the other hand, statistics were not the only valid method of judging a new form of treatment, and he hoped that members of the conference would keep an open mind and not reach conclusions on purely theoretical considerations.[878]

Clearly those supportive of hyperbaric oxygen accepted that they would come under criticism if they did not provide more objective, scientific evidence in support of their research. However, Illingworth, like Hutchison, stressed that clinical experience and observations should be just as valued in clinical research.

The panel dedicated to newborn resuscitation was chaired by the physiologist Kenneth Cross of St Mary's Hospital London, and both Hutchison and Dawes presented papers. As has been discussed, Cross was also a prominent member of the British neonatal network, having been a founding member of the Neonatal

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876 Donald, K. (1964). Fd 23/869 item 34: Letter from Professor KW Donald, University of Edinburgh to Dr Herrald, 12th Feb. *MRC Archives, National Archives*, London.

877 (1964). Fd 23/870 item 78: [cr 64/80] minutes of the conference on hyperbaric oxygen therapy, held on 23rd april 1964. *MRC Archives, National Archives*. London.

878 Ibid.

Society. He had a keen interest in newborn respiration and collaborated extensively with Dawes throughout the early 1960s.

Dawes began by emphasising the two stage model of newborn asphyxia which had been discovered by the Puerto Rican researchers working on rhesus monkeys. As has been discussed, this work had shown that the changes which occurred in newborn mammals during asphyxia were ‘highly predictable’, as was the time to last gasp.[879] Having established the time to last gasp, Dawes had used the agreed resuscitative method of members of the neonatal network, which involved using endotracheal intubation and positive pressure with external cardiac massage when necessary. He argued that the use of positive pressure ventilation caused a drop in the carbon dioxide content of the blood and a rise in oxygen.[880] With sixty successful resuscitations of foetal monkeys, and no cases of pneumothorax, Dawes was convinced of the efficacy of this technique.[881]

Believing that he had established the efficacy of intubation and positive pressure ventilation, Dawes then continued to attack hyperbaric oxygen as a resuscitative method, raising five major criticisms of Hutchison’s technique. Dawes questioned how Hutchison could claim that hyperbaric oxygen was faster and easier to use, when the chamber prevented the often ‘life-saving’ use of external cardiac massage.[882] He disagreed with Hutchison’s claim that under higher pressures oxygen could penetrate the skin in sufficient quantities ‘to enable recovery’, arguing that hyperbaric oxygen failed to treat the build-up of carbon dioxide in the infant’s blood.[883]

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879 Dawes, G. (1964). Fd 23/870 item e15: 'hyperbaric oxygen and the resuscitation of asphyxiated infants at birth', 7th april 1964. *MRC Archives, National Archives*. London.

The last gasp describes the last respiratory movement of rhythmic gasping before the newborn enters secondary apnoea. By this stage members of the neonatal network believed that only infants in secondary apnoea truly required active resuscitation such as intubation. Up to the last gasp it was argued that the newborn could be resuscitated using stimulation such as suctioning the airways and supplying oxygen via a face mask.

880 Ibid.

881 Ibid.

882 Ibid.

883 Ibid.

Like Tizard before him, Dawes criticised Hutchison for failing to identify the stage of asphyxia that each of his cases had reached, and therefore argued that he had failed to show if they actually required resuscitation.[884] Dawes therefore argued that Hutchison's research did not support the claim that hyperbaric oxygen was an effective resuscitative method. Feeling that Hutchison had failed to provide reliable data, Dawes told the conference that he had decided to conduct his own controlled trial of the technique on animals. His research was already underway, and it took into account the stage of asphyxia that the animals were treated at. Dawes reported that the results of this trial would be published shortly.[885]

Having treated 90 cases with hyperbaric oxygen by the time of the conference, Hutchison was able to present more data during his paper. Hutchison also used the conference paper as an opportunity to address many of his critics, so it was more defensive in tone than the *Lancet* paper. He also continued to critique intubation with positive pressure methods. Although Hutchison conceded that intubation and positive pressure ventilation appeared to be the most effective technique in use, he argued that clinicians were faced with a 'major problem' of assessing the efficacy of resuscitation techniques as 'time is on the side of neither baby nor paediatrician, and the recording of scientific measurements is an extremely difficult business'.[886] Hutchison was defending his own research and pre-empting further attacks of his methods.

Although Hutchison admitted that hyperbaric oxygen did not treat the respiratory acidosis of asphyxia, he argued that it effectively treated anoxia and that:

> On a purely physiological basis it seems to suppose that when a severely hypoxic infant is placed in a pressure chamber in pure oxygen at 2 – 4 atmospheres absolute, so that there is a gradient of 1500 – 3000 mmHg between the environment and his plasma and tissue fluids, oxygen will diffuse into the circulating blood.[887]

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884 Ibid.

885 Ibid.

886 Hutchison, J. H. (1964). Fd 23/870 item 54: [m.R.C. 64/406] 'hyperbaric oxygen in the treatment of asphyxia neonatorum'. *MRC Archives, National Archives*. London.

887 Ibid.

He added that experiments on rats had 'clearly demonstrated' this effect.[888] Hutchison further addressed critics by stating that: 'We have, so far, thought it unjustifiable to measure oxygen tensions in the tissue fluids of the human infant due to technical difficulties which would delay the start of treatment.'[889]

Hutchison disregarded the need to treat acidosis and stated that 'the principal aim of any method of resuscitation is to introduce oxygen into the circulating blood', which, he claimed, hyperbaric oxygen achieved more effectively than intubation and positive pressure ventilation.[890] He argued:

> Our experience with hyperbaric oxygen has convinced us that in the same situation, even more rapid correction of the anoxia ensues, with a quick improvement in the heart rate and the establishment of respiration sufficient to rapidly expand the lungs.[891]

In defence of hyperbaric oxygen, which critics had suggested could not expand newborn lungs, Hutchison contended that four of his cases had not gasped at all prior to treatment, yet had made a full recovery in the chamber, suggesting that it had expanded unexpanded lungs.[892] He further attacked intubation and positive pressure ventilation:

> The effects of tracheal intubation in the same situation are also in doubt. We know of no direct evidence obtained from the totally apneic newborn infant that intermittent positive pressure can expand lungs which are completely atelectatic.[893]

Hutchison claimed that his own experience of the technique led him to 'an attitude of scepticism' over its efficacy and conluded that:[894]

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[888] Ibid.

[889] Ibid.

[890] Ibid.

[891] Ibid.

[892] Ibid.

[893] Ibid.

[894] Ibid.

> Unless tracheal intubation can bring about the expansion of completely unexpanded lungs the totally apnoeic infant on the point of death is more likely to have oxygen forced into the circulation when the surrounding pressure gradient is 3000 mmHg [i.e. when treated with hyperbaric oxygen] than when it is 770 mmHg.[895]

In the lively discussion that followed the two papers, most of the points from the *Lancet* debate were raised again, including the need to distinguish the stage of apnoea to truly assess the efficacy of resuscitative techniques. It was apparent that Hutchison was under attack from individuals who represented the neonatal network, including Tizard, Dawes, Cross and Davis. Dawes again suggested that many of Hutchison's cases were in primary apnoea and therefore did not require resuscitation, and he argued that more controlled trials were necessary using fetal animals in secondary apnoea, to assess the true efficacy of the technique.[896] This point was seconded by Cross who commented that: 'Professor Hutchison's results were so far anecdotal in nature.'[897] The participants therefore agreed that a controlled trial comparing intubation and intermittent positive pressure ventilation with hyperbaric oxygen in the treatment of fetal animals in secondary apnoea was needed.[898] However some participants expressed concerns over extrapolating animal results to humans and the possibility of a controlled clinical trial was discussed, but two major objections were raised. It was felt by some that the variables in humans were too great to make such a trial feasible, and secondly 'some groups were so convinced of the efficacy of it [their chosen resuscitative method] that they would consider this unethical.'[899]

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895 Ibid.

896 Dew, R. (1964). Fd 23/870 item 65: Unpagenated handwritten minutes of the conference on hyperbaric oxygen, held on 23rd april 1964. *MRC Archives, National Archives*. London.

897 Nunn, J. (1964). Fd 23/870 item 55e: Notes on conference on hyperbaric oxygen therapy proceedings. *MRC Archives, National Archives*. London.

898 Howarth, S. (1964). Fd 23/870 item 56e: Report on the conference on hyperbaric oxygen therapy. *MRC Archives, National Archives*. London.

899 Nunn, J. (1964). Fd 23/870 item 55e: Notes on conference on hyperbaric oxygen therapy proceedings. *MRC Archives, National Archives*. London.
Howarth, S. (1964). Fd 23/870 item 56e: Report on the conference on hyperbaric oxygen therapy. *MRC Archives, National Archives*. London.

Another major point of contention was Hutchison's claim that oxygen absorption through the skin of a fetal rat was comparable to human infants. Cross argued that the results could not be extrapolated to humans due to the vast differences in surface area to volume ratios between the two.[900] Tizard also repeated his concern regarding the use of changes in skin colour as an indicator for oxygenation, he claimed that oxygen could have diffused through the skin to peripheral tissue, producing the pink colour, regardless of central arterial oxygenation.[901] Many of the participants agreed that the use of the chamber inhibited direct observations and also prevented the use of the often life-saving cardiac massage, although they did agree that some of the dangers of the therapy 'were probably exaggerated'.[902]

The conference reported its overall conclusions to the July 1964 meeting of the Clinical Research Board (CRB), stating that hyperbaric oxygen 'was a new technology needing careful evaluation'.[903] Although a case could be made for supporting facilities for treatment of carbon monoxide poisoning, 'a controlled trial is probably required to establish objectively the value of hyperbaric oxygen in the treatment of asphyxia neonatorum'.[904] The Report agreed with members of the neonatal network that more basic animal and experimental work was required and that, at the present time, work on hyperbaric oxygen should be restricted to a few centres with the suitable personnel and facilities.[905] These recommendations were perhaps unsurprising considering that the remit of the MRC was to promote and co-ordinate clinical science and research in Britain, and it therefore shared the ethos of the neonatal network members, including the value of animal studies and

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Dew, R. (1964). Fd 23/870 item 65: Unpagenated handwritten minutes of the conference on hyperbaric oxygen, held on 23rd april 1964. *MRC Archives, National Archives*. London.

900 Nunn, J. (1964). Fd 23/870 item 55e: Notes on conference on hyperbaric oxygen therapy proceedings. *MRC Archives, National Archives*. London.

901 Ibid.

902 Howarth, S. (1964). Fd 23/870 item 56e: Report on the conference on hyperbaric oxygen therapy. *MRC Archives, National Archives*. London.

903 (1964). Fd 23/870 item 79: [cr 64/81] 'hyperbaric oxygen therapy: Office notes', to be circulated to the c.R.B., 16th july. *MRC Archives, National Archives*. London.

904 Ibid.

905 Ibid.

objective scientific methods as a means of both assessing and informing clinical practice.

The issue of hyperbaric oxygen and newborn resuscitation was considered such a pressing and contentious matter that it was agreed that a working party should be established ‘to examine the possibility of carrying out a clinical trial of high pressure oxygen therapy in respiratory distress and asphyxia of infants’.[906] It was therefore decided that a specific conference on hyperbaric oxygen and respiratory problems of the newborn should be organised as well as the proposed working party.[907] Sir Harold Himsworth, Secretary of the MRC, expressed these sentiments in a letter to Professor Dacie Hubble, Sheffield, whom he asked to chair the working party:

> This point [use of hyperbaric oxygen for newborn resuscitation] ought to be tackled and an attempt made to clarify the situation, I daresay that I need hardly tell you that people seem to be taking up positions already on this subject. I understand that there are some who consider high-pressure oxygen as already obligatory, while there are others who think it is no good and that if it interferes with such things as intermittent positive pressure ventilation, it is bad. I suspect that the truth may well be that high-pressure oxygen is not a panacea for all types of respiratory failure in the newborn, but may be very useful for some.[908]

It was clear that Sir Harold was concerned by the divided situation regarding the use of hyperbaric oxygen in the newborn, and hoped that the proposed Working Party and conference would go some way to resolving the issue. However the division also reflected a more general tension amongst those interested in the care of the newborn. As has been discussed in the previous chapter, from the 1950s a network of academic clinicians and scientists interested in the care of the neonate had emerged. The members of the neonatal network valued the authority of neonatal physiology and basic experimental animal research. However, they represented a small and elite group, and their ethos was not shared by the

906 Godfrey, S. (1964). Fd 23/871: Typed note from dr godfrey to dr herrald regarding further recommendations after the m.R.C.'s first hyperbaric oxygen therapy conference, 16th june. *MRC Archives, National Archives*. London.

907 (1964). Fd 23/871 item 10b: Typescript 'follow up on the hyperbaric oxygen therapy conference', 29th oct. *MRC Archives, National Archives*. London.

908 Himsworth, H. (1964). Fd 23/871 item 5: Letter from sir harold himsworth to professor d.V. Hubble, 5th aug. *MRC Archives, National Archives*. London.

majority of clinicians during the early 1960s, of which Hutchison was a prime example.

The physiologists publish their research

On 12th September 1964 Cross and Dawes published the results of their controlled trial of hyperbaric oxygen on fetal rabbits, which they had mentioned during the MRC Conference.[909] The study compared hyperbaric oxygen to the use of intubation and positive pressure ventilation, and it was presented, perhaps unfairly, as a challenge to Hutchison's claim that 'apnoea neonatorum is not an emergency in which a controlled trial would be permissible'.[910] The physiologists, as prominent members of the neonatal network, argued that by using animal models, such a trial could be conducted, and it also allowed the identification of stages of asphyxia, and therefore provided a more reliable and objective assessment of the efficacy of the techniques.[911]

Cross and Dawes claimed that their research was superior to the Glasgow team's, as they could ensure that they only investigated animals in secondary apnoea, which had already reached the last gasp.[912] Like Tizard they felt it likely that many of Hutchison's original cases were in primary apnoea and did not require artificial resuscitation.[913] Although they conceded that in human infants the time to last gasp had not yet been defined, they still argued that their 'results show that, in asphyxiated fetal rabbits [beyond the last gasp], tracheal intubation and positive-pressure ventilation with oxygen usually led to recovery, while treatment with hyperbaric oxygen was wholly ineffective'.[914] The physiologists concluded that:

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909 Cross, K., G. Dawes, et al. (1964). "Preliminary communication: Hyperbaric oxygen and intermittent positive-pressure ventilation in resuscitation of asphyxiated newborn rabbits." *Lancet* **2**: 560-522.

910 Ibid. p560.

911 Ibid.

912 Ibid.

913 Ibid.

914 Ibid.

> The wisest plan seems to be to act as if the infant had already taken its last gasp and to give ventilation artificially so as to restore the oxygenation of the blood and remove the excess carbon dioxide as soon as possible … [as] no convincing evidence has yet been adduced that the use of high-pressure oxygen chambers is effective after the last gasp.[915]

This paper was significant, not least because it represented the voice of two influential members of the neonatal network, but also because it again highlighted the authority that the network placed on physiology. The network believed that physiologists had a place in clinical debates and valued their contribution to discussion of clinical practice.

The paper prompted a response from Hutchison and his team, which was published in the *Lancet* two weeks later.[916] Hutchison's major issue with the research was his belief that animal studies, especially those on fetal rabbits, could not be translated into clinical practice on human infants. He argued that in humans, the causes of asphyxia were too varied, and therefore could not be compared to rabbits which had been artificially asphyxiated in saline.[917] He further argued that in his clinical experience not all infants responded in the same way to asphyxia, nor did they follow such obvious and predictable stages as the physiologists claimed.[918] Hutchison was not only challenging the relevance of animal research, he was also clearly insulted that two physiologists were questioning the authority and experience of a Professor of Child Health.

Hutchison and his team concluded that:

> The controversy which our paper has aroused has caused us after the most careful consideration and discussion with our obstetricians and anaesthetists, to revise our earlier views regarding a controlled trial.[919]

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915 Ibid.

916 Hutchison, J. H., M. M. Kerr, et al. (1964). "Hyperbaric oxygen in resuscitation of the newborn." *Lancet*: 691-692.

917 Ibid.

918 Ibid.

919 Ibid.

The Glasgow team had therefore decided, due to the continued criticism, to mount a controlled trial to compare the two methods of resuscitation 'fairly under the ordinary conditions of clinical practice'.[920] Hutchison's belief in the superiority of clinical experience over laboratory research was evident. Although he admitted that the trial might not resolve the issue of whether the infants had reached the last gasp, he argued that 'it can probably never be proved to exist in any individual infant because it must never be awaited, and it is certainly uncommon in practice'.[921]

This exchange between Hutchison and the physiologists was considered by those organising the MRC's conference on hyperbaric oxygen and respiratory problems of the newborn. The chair of the MRC's Working Party, Dacie Hubble, visited Hutchison in Glasgow, and admitted that there were 'criticisms to be applied to the clinical investigations since obviously it cannot concern babies who are said to be "beyond the last gasp"'.[922] However, Hubble also found fault with Cross and Dawes' research, commenting that 'it is uncertain whether the drowned rabbit who had been the subject of trauma represents exactly the human situation'.[923] Aware of the tension, Sir Harold Himsworth felt that the whole issue was growing increasingly pressing, as he wrote to Hubble:

> It seems to me that their [Cross and Dawes] results stress the urgency of our having a look at this problem as soon as we can. On the basis of the experimental results, those who dislike hyperbaric oxygen can say that there is an indication that it does harm; the others will doubtless defend their position stoutly. But we all know the difficulty of extrapolating from animals to man and doubt whether asphyxiated rabbits are comparable to babies who havn't [sic] breathed. It would therefore be most valuable to have a pooling of clinical experience to assess what the present indications are on human children.[924]

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920 Ibid.

921 Ibid.

922 Hubble, D.V. (1964). Fd 23/878 item 5: Letter from DV Hubble to Sir Harold Himsworth, 15th Sept, *MRC Archives, National Archives,* London.

923 Ibid.

924 Himsworth, H. (1964). Fd 23/878 item 6: Letter from Sir Harold Himsworth to Professor DV Hubble 17th Sept. *MRC Archives, National Archives*, London.

It was clear that Himsworth was reluctant to dismiss the value of clinical experience, although as head of the MRC he agreed that basic physiological research played an important role in clinical research. Through their correspondence on the planning of the special conference, it was apparent that both Himsworth and Hubble were keen to gather as balanced a group of participants as possible, as they carefully discussed who should be invited, including physiologists, paediatricians and obstetricians.[925]

By 1964 the MoH was also feeling under pressure from the mounting applications for hyperbaric facilities around Britain. George Godber, Chief Medical Officer of the MoH, wrote to Himsworth stressing that the issue was ‘getting more and more pressing’, and asked for some advice.[926] However, Himsworth was aware that on the issue of hyperbaric and neonatal asphyxia, at least, a great deal more time was needed to resolve the issue. He replied to Godber:

> I am afraid that these projects are not likely to move quickly, from the letters and consultations that I have had on the above subjects it is evident that there is real puzzlement as to the potentialities of hyperbaric therapy in asphyxia neonatorum … At the same time there is an anxiety not to overlook any potentialities that there might be, but a reluctance to express opinion as to what these could be on the part of many people. I think that it might well take some time for the views to shake down the position between the extremes of caution and enthusiasm.[927]

Himsworth even considered that a total of three conferences on hyperbaric oxygen and the respiratory disorders of the neonate might be necessary to resolve the divided situation.[928]

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925 (1964-1965). Fd 23/878: File on the conference on hyperbaric oxygen in the treatment of respiratory disorders of the newborn, held 7th january 1965. *MRC Archives, National Archives*. London. This file contains correspondence regarding the planning of the conference.

926 Godber, G. (1964). Fd 23/871 item 9c: Letter from George Godber, to Sir Harold Himsworth, 23rd Oct. *MRC Archives, National Archives*, London.

927 Himsworth, H (1964). Fd 23/871 item 11: Letter from Sir Harold Himsworth to George Godber, 2nd Nov. *MRC Archives, National Archives*, London.

928 Ibid.

The MRC Conference on Hyperbaric Oxygen and the Respiratory Disorders of the Newborn, 7th January 1965

It had been hoped that the Glasgow team would have some preliminary results of their controlled trial ready by Christmas 1964, to be presented at the January conference. However the trial had fallen behind schedule and Hutchison was reluctant to present a paper at the New Year conference.[929] It was decided that Hutchison's paper would outline 'in some detail the control trials…and to present the bare facts as regards survivals and deaths…and giving a brief account of the post mortem findings in death'.[930]

The conference was held on the 7th January 1965, with the aim:

> To discuss the potential value of hyperbaric oxygen treatment of the respiratory disorders of the newborn; and to advise the MRC on further research, including clinical trials, which should be promoted in this field.[931]

The chair, Professor Dacie Hubble, outlined the reason for the meeting, which was to address the divided situation which had arisen regarding the use of hyperbaric oxygen for newborn resuscitation.[932] The main issue was that neonatal physiologists did not understand the physiological action of the treatment, failing to understand how an infant could be resuscitated without expansion of its lungs, and therefore doubting the overall efficacy of the technique.[933]

Since the previous conference, as has been discussed, Cross and Dawes had provided evidence that hyperbaric oxygen failed to resuscitate asphyxiated fetal

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929 Hutchison, J.H. (1964. Fd 23/878 item 34: Letter from JH Hutchison to Sheila Howarth, 7th Dec. *MRC Archives, National Archives*, London.

930 Ibid.

931 (1965). Fd 23/878 item 49: Agenda for the conference on hyperbaric oxygen in the treatment of respiratory disorders of the newborn [m.R.C. 65/1211]. *MRC Archives, National Archives*. London.

932 (1964). Fd 23/870 item 78: [cr 64/80] minutes of the conference on hyperbaric oxygen therapy, held on 23rd april 1964. *MRC Archives, National Archives*. London.

933 Hubble, D. V. (1964). Fd 23/878 item 43: Unpagenated typescript 'chairman's notes', sent by d.V. Hubble to sheila howarth, 21st dec 1964. *MRC Archives, National Archives.* London.

rabbits, and Hutchison had continued to advocate the technique and had mounted a controlled clinical trial.[934] In light of the controversy and new evidence, Hubble asked the conference participants to consider the following four questions:

1. Is hyperbaric oxygen effective in the resuscitation of the apnoeic baby?
2. If it is effective what are the physiological mechanisms involved?
3. Is it as effective as intubation and intermittent positive-pressure inflation of the lungs?
4. What is the comparative practicability of the two methods?[935]

Although Hubble doubted all the issues would be resolved by the end of the conference, he hoped that the progress made would be assessed and that a decision made as to the possible need for further research, and what this would entail.[936]

There was a strong neonatal network presence at the conference, with two of the three papers being presented by prominent members of the network. Leonard Strang, from Tizard's Nuffield Neonatal Research Unit, Hammersmith London, presented the first paper. Strang, who was mentioned in the previous chapter, had just returned from a year in Boston, working alongside Charles Davenport Cook at the Children's Medical Centre. On his return he joined Tizard's team at Hammersmith, with a strong interest in neonatal pulmonary physiology and respiration, and he was also a member of the Neonatal Society.

Strang's paper discussed the mechanisms of oxygen absorption, stressing the difference between the adult and the fetus, arguing that in adults oxygen uptake was dependent on pulmonary blood-flow and that as the haemoglobin was almost fully saturated, hyperbaric oxygen therapy would potentially only increase the oxygen dissolved in the blood plasma.[937] In the fetus only a proportion of the cardiac output passed through the lungs, with the majority shunted through the foramen ovale. In the newborn arterial oxygenation was dependent on the degree

934 Ibid.

935 Ibid.

936 (1964). Fd 23/870 item 78: [cr 64/80] minutes of the conference on hyperbaric oxygen therapy, held on 23rd april 1964. *MRC Archives, National Archives*. London.

of shunt. During asphyxia in the newborn, pulmonary blood vessels constricted and the amount of shunted blood increased. Strang argued that it was very difficult to increase arterial oxygen tension in the presence of a large shunt. However, ‘with the first breath and expansion of the alveoli … a striking increase appears in pulmonary blood-flow with a corresponding diminution’ in shunted blood.[938] He argued that even if oxygen absorption through the skin could be demonstrated, it would prove ineffective due to the low skin blood-flow, as a result of ‘intense peripheral vasoconstriction’ during asphyxia.[939]

In the discussion following Strang’s paper the conference participants agreed that ‘the degree of shunt was the vital factor governing oxygenation of the foetus’ and suggested that it might be best to ‘concentrate on methods of increasing pulmonary blood flow rather than attempting to increase the pO_2 of the arterial blood flow’.[940] Some participants stressed the need for caution when drawing conclusions without any direct evidence, arguing that changes in the degree of shunt under different conditions were not yet known in the human infant, again highlighting some of the concerns surrounding extrapolation from animal research.[941]

The participants further debated the possibility of cutaneous oxygen absorption in the newborn. Although direct evidence of oxygen absorption was lacking, some considered it could be possible at four atmospheres, pointing to some obscure 30 year old research quoted in a 1957 edition of *Physiological Reviews*.[942] It was argued that the reports of dead babies in incubators remaining or turning pink, could be evidence of skin absorption. However, others pointed out that this might

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937 Strang, L. (1965). Fd 23/878 item 49: 'some theoretical considerations in the use of hyperbaric oxygen for newborns', paper by l.B strang. *MRC Archives, National Archives*. London.

938 Ibid.

939 Ibid.

940 (1965). Fd 23/878 item c.R.65/28: Minutes of the conference on hyperbaric oxygen in the treatment of respiratory disorders of the newborn, 18th march. *MRC Archives, National Archives*. London.

941 Ibid.

942 Ibid.

have been due to inactivation of enzymes at a low pH.[943] It was also argued that Boston investigators had shown dramatic drops in arterial oxygen tension in infants in hyperbaric chambers who had stopped breathing.[944] The chair concluded that further investigation of the possibility of skin diffusion should be investigated.[945]

The neonatal network was also represented by the second paper, which was given by Cross and Dawes. The paper presented a fuller account of their controlled trials on fetal rabbits which had been published as a preliminary communication in the *Lancet* in 1964.[946] Their research had shown that positive pressure ventilation with oxygen was ‘significantly more effective than other methods’, although they did concede that hyperbaric oxygen appeared more effective than 100 per cent oxygen at atmospheric pressure.[947] However, they stressed that positive pressure ventilation had several advantages over hyperbaric oxygen. Firstly, positive pressure methods actively expanded the lungs, pushing oxygen into them, which was especially important in cases where insufficient alveoli had been expanded.[948] Their previous work had shown that hyperbaric oxygen was ineffective when the lungs had not been expanded.

Critical of Hutchison’s descriptions of recovery in his cases, Cross and Dawes emphasised what they considered the correct sequence of recovery which should be observed in successful cases. The appropriate signs of recovery followed the order: a rise in heart rate, then a rise in blood pressure, which was followed by gasping, the newborn would then turn pink about 1½ minutes after the heart rate

943 Ibid.

944 Ibid.

945 Ibid.

946 Cross, K., G. Dawes, et al. (1964). "Preliminary communication: Hyperbaric oxygen and intermittent positive-pressure ventilation in resuscitation of asphyxiated newborn rabbits." *Lancet* **2**: 560-522. {Anon, 1965 #700}

947 (1965). Fd 23/878 item c.R.65/28: Minutes of the conference on hyperbaric oxygen in the treatment of respiratory disorders of the newborn, 18th march. *MRC Archives, National Archives*. London.

948 Ibid.

had accelerated.[949] Cross and Dawes stressed that oxygen uptake did not significantly increase until gasping had occurred, as this both aerated the alveoli and increased pulmonary blood flow.[950]

The second major advantage of positive pressure ventilation was that it facilitated rapid elimination of carbon dioxide and a resultant rise in pH, which was known to lead to rapid improvements in the animals' condition.[951] Thirdly the incidence of heart block was significantly reduced when using positive pressure, and if it did occur the animal was easily accessible for external cardiac massage.[952]

During the discussion following Cross and Dawes' paper further 'doubts were expressed as to whether the animals in these experiments were comparable to the clinical cases needing treatment'.[953] One participant also expressed the view that 'the often traumatised asphyxiated infant also might tolerate less well the traumatic handling involved during intubation than the animal which was born fit and then asphyxiated artificially'.[954] Participants clearly questioned how a traumatised asphyxiated human newborn could be reliably compared to a healthy fetal rabbit artificially asphyxiated with saline. This further highlights the concerns surrounding the possible dangers of intubation and positive pressure ventilation, including not only possible barotrauma to the lungs, but also the potential damage to the upper airways from misguided or unskilled intubation technique.

The final paper was presented by Hutchison, and his tone and rhetoric reflected that of the debate which had played out in the pages of the *Lancet*.[955] The paper re-iterated all of Hutchison's defensive points, including his claim that animal trials could not be easily extrapolated to clinical cases. Hutchison appeared to be

949 Ibid.

950 Ibid.

951 Ibid.

952 Ibid.

953 Ibid.

954 Ibid.

955 Hutchison, J. H. (1965). Fd 23/878 [m.R.C. 64/1208]: 'hyperbaric oxygen in asphyxia neonatorum', j.H. Hutchison. *MRC Archives, National Archives*. London.

personalising the issue as he emphasised his wealth of clinical experience, which he argued was equal to, if not superior to, the physiologists' scientific data. He stated: 'It is my experience that the asphyxiated human baby is quite rarely born beyond the stage of the last gasp. When he is, it can only be occasionally that any method of resuscitation will succeed.'[956] He further argued that 'in his clinical opinion' it was impossible to judge whether the infant was beyond the last gasp.[957]

Hutchison then began to attack intubation and positive pressure ventilation stating that:

> I do not think it is easy to instruct an ever changing series of junior staff in the technique of tracheal intubation. And we should not forget that a not insignificant proportion of severely asphyxiated infants have suffered irreversible damage [from this technique].[958]

He further claimed that the need to provide senior staff to perform intubation had taxed the Glasgow hospital's resources 'to the limit', and that he did not believe the average maternity unit could provide this.[959] The remainder of his paper detailed the methods involved in his controlled trial, still underway in Glasgow, which compared the two techniques. Although the trial was not yet finished, Hutchison was able to provide some raw data, and he believed that this supported the continued use of hyperbaric oxygen.

The discussion following Hutchison's paper raised the major points of contention which had been discussed in the *Lancet*. The majority of participants agreed that there was a need for more objective scientific measurements of the infant's blood, such as the pH and pO_2. The relevance of basic animal research to clinical cases was raised. Peter Tizard stressed the importance of a thorough understanding of the physiological changes which occur during asphyxia which had been charted by researchers. He argued that:

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956 Ibid.

957 (1965). Fd 23/878 item c.R.65/28: Minutes of the conference on hyperbaric oxygen in the treatment of respiratory disorders of the newborn, 18th march. *MRC Archives, National Archives*. London.

958 Hutchison, J.H. (1965). Fd 23/878 [MRC 64/1208]: 'hyperbaric oxygen in asphyxia neonatorum'. JH Hutchison. *MRC Archives, National Archives*, London.

959 Ibid.

> When assessing the value of hyperbaric oxygen it was important to differentiate those babies who became pink and then gasped, who might well be said to have been resuscitated by oxygen therapy, and those who gasped and then became pink in whom other stimuli may have been at work.[960]

Tizard was basically highlighting what he saw as a possible flaw in the evaluation of resuscitative techniques, which had relied on clinical observations, and which failed to understand the importance of the sequence of physiological changes. He explained that babies in terminal apnoea fell into two categories: those who were born with completely unexpanded lungs and made no respiratory attempts at birth, and would not go pink in the presence of oxygen; and those who had made some respiratory movements at birth and then became apnoeic, who had some expanded alveoli, and would therefore go pink in oxygen before gasping commenced again.[961] Tizard conceded that hyperbaric oxygen could therefore be of some benefit to the infants in the latter group. However, as it was difficult to determine the category of apnoea in human infants, he advocated the intubation of all apnoeic infants.[962]

The discussion then turned to the concern over the inherent dangers of intubation if performed by untrained persons. However, 'a view was expressed that all labour ward staff should be trained to intubate and it was stated that in Derbyshire head midwives already received instruction in the method'.[963] Although participants were not dismissing the use of hyperbaric oxygen, they did appear to agree that its use was limited to the treatment of infants with partially expanded lungs, which made the treatment redundant in their eyes. However, as there were still concerns over the technical difficulty of intubation and positive pressure methods, participants discussed the problem of domiciliary births. It was suggested that general

960 (1965). Fd 23/878 item c.R.65/28: Minutes of the conference on hyperbaric oxygen in the treatment of respiratory disorders of the newborn, 18th march. *MRC Archives, National Archives*. London.

961 Ibid.

962 Ibid.

963 Ibid.

practitioners and midwives should be instructed in the use of mouth-to-mouth insufflation, or mouth-to-endotracheal tube.[964]

As the conference came to a close, the chair, Hubble, 'expressed the hope of the conference that Professor Cross and Dr Dawes would continue their animal experiments in this field'.[965] The over-riding consensus was that hyperbaric oxygen therapy would undoubtedly help those in primary apnoea; but in cases of secondary apnoea, where the lungs were unexpanded, only intubation and positive pressure ventilation would be effective.[966] Although it was agreed that most human cases were in primary apnoea, in which both methods could be shown to be effective, it was still argued by Cross and Dawes, that intubation and positive pressure was 'the better method'.[967] It was further stressed that, as it was difficult to assess the stage of asphyxia in clinical cases, it should be assumed that all cases were in secondary apnoea, for which only intubation and positive pressure was effective.[968] The conference concluded that some sort of article or statement should be prepared for publication, and Tizard was asked if he would summarise the conference's findings and draft this.

This conference reflected some of the major tensions amongst the British medical community concerned with the care of the newborn at the time, namely the conflict surrounding the need for clinical trials and objective scientific methods, and the concerns about the extrapolation of animal research to clinical practice. It highlighted the growing authority of the neonatal network. They were not only seeking to specify the most effective treatment of asphyxia neonatorum, but were also redefining both the conception of newborn asphyxia and the general requirements for resuscitation. The network, which still constituted a small and elite group, was beginning to influence clinical practice more generally, by providing official recommendations concerning newborn resuscitation. Hutchison,

964 (1965). Fd 23/878 item c.R.65/28: Minutes of the conference on hyperbaric oxygen in the treatment of respiratory disorders of the newborn, 18th march. *MRC Archives, National Archives*. London.

965 Ibid.

966 Ibid.

967 Ibid.

968 Ibid.

who was not a member of the network, clearly did not share their enthusiasm for basic animal experiments, and their conception of asphyxia and the requirements for resuscitation. Hutchison failed to grasp the two stage construction of asphyxia, which stressed the different requirements of an infant in primary and secondary apnoea. He still argued that the main requirement for resuscitation was the supply of oxygen, whereas the members of the network had expanded this to include expansion of the lungs and external cardiac massage.

Interestingly, although the conference seemed to have provided evidence of several major flaws in hyperbaric oxygen, the technique was not blatantly dismissed. The neonatal network felt strongly that intubation and positive pressure methods were the most effective, and that Hutchison's research did not stand up to objective scientific scrutiny, but they did not explicitly state this. In part, this reflects the wider context of the British paediatric community. Hutchison was a well respected and senior paediatrician, and was an authority within the British Paediatric Association and would be elected as President in 1968. The BPA also included members of the neonatal network such as Tizard and Strang. So this reluctance may have reflected a professional courtesy, which was further influenced by the fact that Hutchison had effectively personalised the conflict by putting not only hyperbaric oxygen but also his clinical experience and ability as a clinician up for criticism. Either way this reflects a common trend in medical culture, which has been commented on by sociologists, such as Robert Nye, who describes it as a 'Field of Honor'.[969]

The controlled animal and clinical trials are published.

Cross and Dawes published the results of their finished animal trials in the *Journal of Pediatrics* in February in 1966.[970] If one considers that the earlier part of the debate over hyperbaric oxygen and asphyxia neonatorum had been published in the *Lancet*, their decision to publish in this journal was significant. The *Journal of Pediatrics* targeted an international audience of paediatricians, the medical specialists who by 1966 were mainly responsible for the care of the newborn. As

969 Nye, R. (1997). "Medicine and science as masculine 'fields of honor'." *Osiris* **12**: 60-79.

970 Campbell, A. G. M., K. Cross, et al. (1966). "A comparison of air and oxygen in a hyperbaric chamber or by positive pressure ventilation, in the resuscitation of newborn rabbits." *Journal of Pediatrics* **68**(2): 153-163.

the emerging sub-specialty of neonatology still lacked a specific journal, this was a tactical move. It would appear that Cross and Dawes were hoping that this article would provide the definitive end to the controversy, in part by appealing to neonatologists on both sides of the Atlantic, which the 1965 MRC conference had failed to achieve. They clearly felt that their research provided conclusive evidence that intubation and positive pressure ventilation was ‘the most effective method’ for the resuscitation of the asphyxiated newborn.[971]

Cross and Dawes argued that the physiological changes were consistent between rabbits and human newborns, so their work could be extrapolated to humans.[972] They had conducted three different trials, the first of which challenged the Glasgow team’s claim that hyperbaric oxygen was the most effective method of resuscitating an asphyxiated newborn. They decided to test their theory by artificially asphyxiating fetal rabbits, until after the last gasp. The rabbits were then treated with either hyperbaric oxygen or intubation with positive pressure ventilation and cardiac massage. They reported 83 per cent success rate with intubation, and 100 per cent mortality with hyperbaric oxygen, arguing that this was definitive evidence that intubation with positive pressure ventilation should be the preferred method.[973] Cross and Dawes also tested Hutchison’s claim that sufficient oxygen could be absorbed through the newborn’s skin to influence recovery. After a second controlled trial the physiologists concluded that ‘direct access to the lungs was necessary for resuscitation even in this very high oxygen partial pressure’.[974]

Cross and Dawes were again not completely dismissive of hyperbaric oxygen, conceding that it could prove useful for infants with partially inflated lungs, i.e. those infants who had taken a few gasps at birth before becoming asphyxiated.[975] However, as intubation and positive pressure had also proved effective in these situations, they still concluded that it should be the preferred method, stating:

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971 Ibid.

972 Ibid.

973 Ibid.

974 Ibid.

975 Ibid.

> Positive pressure ventilation with air or O_2 rapidly expands the lungs, facilitates the uptake of O_2 and elimination of CO_2, and leaves the infant freely accessible for clearing the airway and giving external cardiac massage if necessary. The observation that it is more effective than exposure to hyperbaric O_2 as a means of resuscitation in young rabbits is consistent with physiologic principles, which should also apply in other species.[976]

Clearly fearing that Cross and Dawes' paper would not be the final word on the matter, the editor of the *Journal of Pediatrics*, Charles Davenport Cook devoted his editorial to the issue. As has been mention, Cook was one of the leading members of the American East Coast neonatal network, and was an important figure in the early careers of many of the British and American network members. So his editorial represented an authoritative voice of the neonatal network, as well as carrying the influence of an internationally respected paediatrician and specialist in neonatal care.

Cook stressed what had been widely accepted by 1966 that the neonate was unique as a patient, as it was often afflicted by 'acute and usually puzzling problems'.[977] He explained that this was often due to the fact that:

> Not only is the human neonate small, and hence technically difficult to evaluate by clinical or laboratory examinations, but the most important part of his past history has occurred in utero, where his status is almost totally hidden from documentation or investigation.[978]

He agreed that resuscitation and the assisted ventilation of the neonate was a critical problem, and that it was therefore understandable that so many solutions to the problem had been suggested. However, with the offering of these varying techniques, Cook identified one of the major conflicts of medicine, that between clinical science and clinical practice, which had also been raised throughout the hyperbaric oxygen controversy.

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976 Ibid.

977 Cook, C. (1966). "Treatment of respiratory failure of newborn infants." *Journal of Pediatrics* **68**(2): 327.

978 Ibid.

Even though he agreed that controlled clinical trials of new therapies were essential, he stated that with regards to resuscitation of the newborn, the situation was further complicated. Cook argued that although it was unethical to subject neonates to untested treatments, it was also unethical to deny life-saving treatment in the name of a randomised controlled study.[979] He therefore stated that:

> In the absence of actual evidence from clinical trials to support a suggested mode of therapy, clinicians should demand, at least a rationale based on sound physiologic or biochemical knowledge plus experimental data from animal studies.[980]

It is clear that although Cook understood the concerns of some clinicians, including Hutchison, he was explicitly supporting the ethos of the neonatal network which valued the research of neonatal physiologists. Cook further explicitly challenged Hutchison, and those who doubted the authority of physiology when he remarked:

> Since the use of improper techniques may be harmful per se or may delay or prevent appropriate therapy, it would seem obligatory that new approaches to therapy be documented whenever possible before they are suggested to clinicians eager for help in the treatment of severe and poorly understood conditions. The two experimental studies cited [those of Cross and Dawes and Hutchison] indicate the vital importance of animal experimentation in the field of practical therapeutics, particularly in the case of the neonate.[981]

This was quite a major blow to the Glasgow group who had effectively been criticised by an international authority in newborn care in an international paediatric research journal. Cook was accusing the Glasgow team of lacking the physiological knowledge and clinical research skills to participate in the neonatal research arena.

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979 Ibid.

980 Ibid.

981 Ibid.

Hutchison also published the results of his clinical controlled trial of hyperbaric oxygen and intubation and positive pressure ventilation in 1966 in the *Lancet*.[982] The paper was obviously highly defensive in tone and Hutchison attempted to justify his position as a clinician stating that:

> It is understandable that the physiologist writing on the subject of neonatal resuscitation should insist upon preliminary animal experimentation. But the clinician faced with an immediate problem of the survival of his patient in the delivery room may find it difficult to accept that the experimental model always accurately reflects the situation in the newborn baby.[983]

Hutchison was stressing his belief that his personal clinical experience and abilities as a clinician were superior to the views of laboratory-based physiologists. He was not only defending hyperbaric oxygen, but clearly reacting to the perceived intrusion of basic scientists into the clinical domain.

Their clinical trial had been conducted in the Glasgow Queen Mother's Maternity Hospital and Glasgow Royal Maternity Hospital for 6 and 16 months respectively. Far from showing the clear efficacy of one technique over the other, the trial indicated 'that under everyday conditions of obstetric practice' they were 'equally effective methods of infant resuscitation'.[984] So in defence of hyperbaric oxygen the Glasgow team continued to discuss the drawbacks they believed intubation and positive pressure ventilation carried. They argued that the higher level of skill required for the use of the technique had 'stretched the resources of the two teaching hospitals to the utmost'.[985] They reasoned that it could not be 'easily or safely' taught to more junior staff, whereas hyperbaric oxygen was 'exceedingly simple', with no risks attached.[986]

In further defence of hyperbaric oxygen Hutchison continued to address the physiological criticisms the treatment had received. He argued that in his vast

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982 Hutchison, J., M. Kerr, et al. (1966). "Controlled trials of hyperbaric oxygen and tracheal intubation in asphyxia neonatorum." *Lancet* **1**(7774): 935-939.

983 Ibid. p935.

984 Ibid. p938.

985 Ibid. p938.

986 Ibid. p938

clinical experience the majority of infants made at least a few feeble gasps at birth and therefore had a few expanded alveoli. He therefore reasoned that as hyperbaric oxygen had been proven effective in the treatment of infants with partially expanded lungs, it would be an effective treatment for asphyxiated newborns. Interestingly, Hutchison and his team accepted some of the points that Cross and Dawes had argued regarding the treatment. However they had come to a different conclusion than the physiologists, based on their clinical experience. The Glasgow team reasoned that as their clinical experience had shown that a newborn with totally unexpanded lungs was rare, then the argument that hyperbaric oxygen was not effective in treating these cases was therefore irrelevant.[987] They questioned the applicability of animal research to human cases, and stressed the inherent difficulties in conducting true controlled clinical trials on babies.[988] They concluded that it was:

> … essential that any method of resuscitation should be demonstrably effective in relieving asphyxia neonatorum in the human infant in the usual situations of obstetric practice, that it should be simple to implement by doctors and midwives, and that with reasonable safe-guards it should be free from risks. We believe that our trials would justify such claims for hyperbaric oxygen. If it is no more effective than tracheal intubation in expert hands it is certainly simpler to apply and safer in the hands of the majority.[989]

They could not argue that hyperbaric oxygen was more effective than intubation and positive pressure methods, so they reasoned that it was simpler to use and therefore should be the preferred method.

The Glasgow team's research was subjected to criticism from prominent members of the neonatal network. This time it was Dr William Silverman, who worked alongside Virginia Apgar at Columbia University, New York. Silverman was concerned by the so-called clinical research methods employed by the Glasgow team, and criticised their analysis of the data.[990] By the mid-1960s Silverman had emerged as an advocate of accurate evidence-based medicine in neonatology,

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987 Ibid. p938.

988 Ibid. p938.

989 Ibid. p938.

990 Silverman, W. A. (1966). "Treatment of asphyxia neonatorum." *Lancet* **2**: 168-169.

and was therefore concerned by Hutchison's team's claims to have conducted a controlled trial.[991]

Arguing that as 'it was most unlikely that the two resuscitative methods… will lead to an *identical* result', Silverman challenged the claim that 'no significant difference' had been found between the effectiveness of both techniques.[992] He criticised the overall design of the trial, including the sample size used and the statistical analysis of the results.[993] He implied that the Glaswegians had failed to mount an appropriate trial capable of assessing the effectiveness of both techniques, and that this had masked the ineffectiveness of hyperbaric oxygen. This letter represented a major attack on the authority and ability of Hutchison and his team.

Hutchison's team was given an opportunity to address Silverman's critique and attempted to answer each of the points raised. Although they agreed that a bigger sample size would have been desirable, they argued that their research was limited by resources.[994] They did not deny the possibility of a true difference in the efficacy of the two techniques, but argued that their research had failed to reveal one.[995] They went on to say that their sample size had been determined by the estimated time needed to complete the trial and the availability of appropriately trained staff to perform intubations.[996] The Glasgow team attacked intubation and positive pressure inflation, arguing that 'even more significant than the mortality figures' were the post-mortem findings, which suggested that two of the failed

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Oransky, I. (2005). "Obiturary: William silverman." *Lancet* **1**: 116.
Silverman, W. (1980). *Retrolental fibroplasia: A modern parable.* New York & London, Grune and Stratton.
Silverman, W. (1985). *Human experimentation: A guided step into the unknown*. Oxford, OUP.
Silverman, W. (1992). "Overtreatment of neonates? A personal retrospective." *Pediatrics*: 971-976.

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Silverman, W. A. (1966). "Treatment of asphyxia neonatorum." *Lancet* **2**: 168-169.

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Ibid.

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Hutchison, J. H., M. M. Kerr, et al. (1966). "Treatment of asphyxia neonatorum." *Lancet* **2**: 169.

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Ibid.

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Ibid.

intubation cases had no severe pathology, and could therefore have been saved.[997]

A further blow to hyperbaric oxygen was provided by the publication of another trial of hyperbaric oxygen conducted on asphyxiated rabbits, by the paediatrician Herbert Barrie, of St Thomas' Hospital, London.[998] Barrie, who has already been mentioned, had spent time in Boston where he had been introduced to intubation by Virginia Apgar, and had returned to Britain, emerging as the leading advocate of the technique during the 1960s. Barrie was quick to undermine Hutchison's research, stating that 'despite theoretical considerations and experimental evidence to the contrary, the use of hyperbaric oxygen in neonatal resuscitation is still being advocated'.[999] Barrie argued that Hutchison had failed to substantiate his claim that 'significant amounts' of oxygen could be absorbed through the skin and respiratory tract of the newborn, and he hoped that his research would provide the relevant contradictory evidence.[1000]

In his discussion Barrie stated that:

> …a constant finding, whether hyperbaric oxygen was given or not, was the rapid development of a respiratory and metabolic acidosis. The relentless fall of pH can only be due to oxygen lack and carbon-dioxide retention, and is a contraindication to the use of hyperbaric oxygen as the sole method of resuscitation.[1001]

He therefore argued that hyperbaric oxygen failed to treat respiratory acidosis and was therefore ineffective at treating asphyxia neonatorum. Barrie further suggested that the 'apparently satisfactory arterial oxygen tensions' reported by Hutchison, were likely due to technical problems of sampling and should not be used as evidence that hyperbaric oxygen was effective.[1002] Barrie concluded that

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997 Ibid.

998 Barrie, H. and G. Miller (1966). "Blood-gas tensions during apnoea in hyperbaric oxygen." *Lancet* **2**: 1394-1396.

999 Ibid. p1394.

1000 Ibid. p1394.

1001 Ibid. p1394.

1002 Ibid. p1395.

their ‘findings support other experimental evidence in apnoeic animals, that hyperbaric oxygen is an ineffective method of resuscitation and that its use in the apnoeic human infant should be discouraged’.[1003]

Two other significant papers were published by leading members of the neonatal network in 1966 and 1967, which represented an attempt by the network to disseminate their views regarding newborn resuscitation in Britain. The first paper was published by Cross in the *British Medical Bulletin* and was an attempt to assess the current physiological understanding of asphyxia and to promote the importance of restoring effective circulation for effective resuscitation.[1004]

Cross hoped to address the divided opinions regarding newborn resuscitation which had become very apparent over the previous fifteen years, as well as to advance his belief that fetal animal studies were an invaluable tool for the evaluation of newborn care and the elucidation of a better understanding of newborn physiology.[1005] He described in detail the two-stage model of asphyxia neonatorum which had been described by both Dawes and Godfrey in Oxford working on fetal rabbits, and also the Puerto Rican research group, working on rhesus monkeys.[1006] Cross clearly believed that these animal studies could be extrapolated to human infants, and attempted to convince the reader of this.

Based on his physiological understanding of neonatal asphyxia, Cross argued that intubation with intermittent positive pressure ventilation and the addition of external cardiac massage was the most logical and most effective treatment.[1007] He further used his physiological knowledge to explain why he believed both intragastric oxygen and hyperbaric oxygen could not be effective methods.[1008] He stressed that the main requirements in resuscitation of an asphyxiated newborn were the supply of oxygen and restoration of effective circulation, which were best achieved

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[1003] Ibid. p1395.

[1004] Cross, K. (1966). "Resuscitation of the asphyxiated infant." *British Medical Bulletin* **22**(1): 73-78.

[1005] Ibid. p73.

[1006] Ibid. p74-75.

[1007] Ibid. p77.

[1008] Ibid. p77.

through the expansion of the lungs using positive pressure and external heart massage. Cross was not only promoting the favoured resuscitative technique of the neonatal network, he was also promoting the ethos that a sound understanding of basic physiology and animal research should form the basis of newborn care.

Tizard also attempted to promote the views of the neonatal network regarding newborn resuscitation when he and a colleague published a similar article in the *Lancet* in 1967.[1009] He addressed the concerns surrounding the extrapolation of animal research findings, which had led to the two-stage model of asphyxia neonatorum, to human babies by reporting on his observations of almost 1,600 newborns delivered at the Hammersmith Hospital.[1010] He stated that he was concerned by the lack of consensus on the most appropriate resuscitative method for the newborn, arguing that 'what is fashionable one year is out of date the next'.[1011] Having observed a substantial number of newborns at birth, Tizard felt able to conclude that the sequence of events observed in fetal monkeys and rabbits, and other mammals, was identical to those in humans.

In light of their observations Tizard argued that it appeared 'that the majority of apneic newborn babies are in primary apnoea'.[1012] However he felt that the clinician could not 'confidently distinguish' the stage of apnoea in every newborn, and recommended that clinicians assume that 'all apnoeic newborn babies are in the state of terminal apnoea, and proceed to intubate'.[1013] This paper not only supported the neonatal network's preferred method of newborn resuscitation, but also promoted the importance and relevance of basic physiology for the future improvement of newborn care.

1009 Gupta, J. and J. Tizard (1967). "The sequence of events in neonatal apnoea." *Lancet* **2**: 55-59.

1010 Ibid.

1011 Ibid. p55.

1012 Ibid. p56.

1013 Ibid. p58.

A Second MRC Special Meeting

With the publication of the controlled trials, and the continued divided opinions on the subject of hyperbaric oxygen and newborn resuscitation, the MRC decided to hold a further special meeting on the issue in 1967.[1014] This meeting was held on 24th July and many of the previous attendees and interested parties were invited to attend. It was hoped that the meeting would not go over old ground, but would discuss the further work which had been conducted and in light of this, ‘decide whether further work in the field … [was] necessary or whether the meeting … [was] in a position to make a definite assessment of the value of hyperbaric oxygen therapy in treating neonatal asphyxia’.(1967)

Professors Cross, Hutchison and Tizard were again asked to present papers on their research and opinions to date, with Professor Dacie Hubble again acting as chair.[1015] All current research was reviewed and the discussion soon veered towards the experimental physiological work of Cross and Dawes, who had argued that hyperbaric oxygen failed to treat those infants in terminal/secondary apnoea with fully collapsed lungs.[1016] However, Hutchison not only criticised the extrapolation of animal research to clinical cases, but also argued that in his ‘clinical experience’ most infants were born in primary/pre-terminal apnoea and had partially expanded lungs.[1017] He contended that animal research on newborns with unexpanded lungs was irrelevant to the discussion. Some participants shared Hutchison’s concerns, and there was discussion regarding the possibility of determining the stage of asphyxia in newborns as well as having specific indicators for urgent resuscitation.[1018]

Hutchison had continued to gather supportive evidence for his use of hyperbaric oxygen in newborn resuscitation, and presented some of his preliminary blood-

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1014 Godfrey, M. (1966). Fd 23/881 item 5: Letter from m. Godfrey, m.R.C., to r.L. Cohen, ministry of health, 24th march, 1966. *MRC Archives, National Archives*. London.

1015 {Anon, 1967 #709}

1016 (1967). Fd 23/885 m.R.C. 67/1216: Minutes of the committee on hyperbaric oxygen therapy, 24th jul 1967. *MRC Archives, National Archives*. London.

1017 Ibid.

1018 Ibid.

oxygen studies.[1019] In an attempt to address his critics he had adopted one of the newer research methods of using pO_2 electrodes which could measure oxygen tensions in the tissues of infants treated with hyperbaric oxygen. Although he had not completed his study, he was able to present details of four cases.[1020]

Tizard was unimpressed with Hutchison's latest research and argued that since all of the cases had been seen to gasp 'the satisfactory results [reported] were not surprising'.[1021] He further stated that in such cases, where the infant had gasped, no sophisticated resuscitation was required as 'a mask with a high air flow would be adequate treatment'.[1022] Tizard stressed the general consensus of the neonatal network, that cases of primary apnoea or where the infant had been seen to gasp need only be treated with oxygen supplied via a face mask. Whereas those cases where the stage of asphyxia was undetermined or thought to be secondary/terminal apnoea, intubation should be the preferred method. Tizard stressed that physiological research had determined that only those infants in secondary/terminal apnoea required more sophisticated resuscitation, and that resuscitative techniques should be evaluated by their ability to treat infants at this stage of asphyxia.

Although some participants shared some of Hutchison's concerns, it was clear that the majority agreed with the consensus of the neonatal network. It also appeared that the once common concern about the safety and difficulty of intubation was dissipating, as the Central Midwives Board were reportedly beginning to teach intubation to midwives to improve the domiciliary care of newborns.[1023]

The MRC did not produce an official declaration on the subject, but a Special Sub-committee of the Standing Medical Advisory Committee of the Scottish Home and Health Department had been established in 1965 to evaluate the uses and

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1019 Ibid.

1020 Ibid.

1021 Ibid.

1022 Ibid.

1023 Ibid.

dangers of oxygen therapy.[1024] Hyperbaric oxygen for newborn resuscitation was within the committee's remit. The Committee was comprised of leading Scottish clinicians, including Hutchison, and Ministry of Health representatives.[1025] In light of the continued controversy the Committee contacted the MRC for an official voice on the subject, especially since the main advocate of hyperbaric oxygen was a key member of the committee.[1026] Sheila Howarth of the MRC was unsure of how to reply to the Committee request and so she approached Sir John McMichael, Chairman of the general Hyperbaric Oxygen Therapy Standing Committee, for advice.[1027] McMichael told Howarth that:

> The Scottish Home and Health Department should be informed that there is no evidence to suggest that hyperbaric oxygen installations are necessary for the treatment of neonatal asphyxia. Other methods of management seem to be equally effective, although this may require tracheal intubation on occasions.[1028]

This statement was forwarded to the Scottish Home and Health Department. It was clear that the official view from the MRC was that hyperbaric oxygen had not been proven to be more effective than intubation with positive pressure ventilation, and that it had the added disadvantage of being large and cumbersome and it could not be used in domiciliary care.

Despite this statement from the MRC, the Scottish Home and Health Department's sub-committee did not dismiss hyperbaric oxygen in their final report published in 1969. The report, *Uses and Dangers of Oxygen Therapy: A Report of the Sub-Committee of the Standing Medical Advisory Committee*, dedicated a section to

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1024 [Anon] (1965). H.H. 109/24: Item 2: Minutes of the 1st meeting of the standing medical advisory committee (scotland) oxygen therapy sub-committee, 9th nov 1965. *Scottish Home and Health Department Archives*. Edinburgh.

1025 Ibid.

1026 [Anon] (1966). H.H. 109/24: Item 10: Minutes of the 5th meeting of the standing medical advisory committee (scotland) oxygen therapy sub-committee, 22nd sep 1966. *Scottish Home and Health Department Archives*. Edinburgh.

1027 Howarth, S. (1967). Fd 23/885 item 38: Letter from S Howarth to J McMichael, 7th Dec. *MRC Archives, National Archives,* London.

1028 McMichael, J (1967). Fd 23/885 item 40: Letter from J McMichael to S Howarth, 10th Dec. *MRC Archives, National Archives*, London.

the use of oxygen for newborn resuscitation.[1029] It agreed that in mild cases of asphyxia oxygen should be given using a face-mask, and that this was also the treatment available to midwives confronted with an asphyxiated newborn.[1030] However in more severe cases of asphyxia it recommended two treatments: intubation and positive pressure ventilation, and hyperbaric oxygen. It argued that intubation with positive pressure ventilation was ‘only practicable in hospitals where trained staff and suitable apparatus [were] immediately available’.[1031] It then stated that:

> It had been shown conclusively that the use of hyperbaric oxygen as specified by… workers gives results equalling those obtained by intubation and intermittent positive pressure inflation by highly qualified practitioners (consultants and selected registrars).[1032]

The report further argued that the subcommittee felt that:

> …whereas the hyperbaric procedure used by Hutchison and his colleagues could be carried out with only a minimum of special training, there was considerable doubt that the high standards of intubation and ventilation in the controlled study pertained generally.[1033]

It was clear that the sub-committee had completely disregarded the views of the MRC and was somewhat influenced by Hutchison’s presence on the committee, which led to its support of hyperbaric oxygen for newborn resuscitation.

In a final attempt to address his critics Hutchison and his colleagues published their results of the use of the membrane electrodes for the measurements of partial pressure of oxygen in the newborn’s blood during treatment with either intubation and positive pressure or hyperbaric oxygen in 1968.[1034] Believing that ‘the principal demand of the anoxic baby’ was for oxygen, Hutchison and

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1029 [Anon] (1969). *Uses and dangers of oxygen therapy: A report of the sub-committee of the standing medical advisory committee*. Edinburgh, H.M.S.O.

1030 Ibid. p37.

1031 Ibid. p37.

1032 Ibid. p37.

1033 Ibid. p37.

colleagues argued that hyperbaric oxygen was shown to raise the partial pressure of oxygen in the asphyxiated newborn's tissue.[1035] Although they also found intubation and positive pressure ventilation to be effective in raising tissue $p0_2$ levels, they still viewed this technique as inferior to hyperbaric oxygen, mainly due to the higher level of skill required to use it.

Hutchison and his team held particular views on the requirements for successful resuscitation. They also continued to argue that the majority of asphyxiated newborns would have partially expanded lungs. Both of these views were in contrast to those of the neonatal network, who believed that resuscitation also required inflation of the lungs and treatment of the respiratory acidosis. As has been discussed, the neonatal network also valued the use of animal research, which had shown how an asphyxiated infant could be in either primary asphyxia or secondary asphyxia, and that this was often difficult to determine in the human newborn. The network members had come to the consensus that it was best to assume that all asphyxiated newborns had reached secondary apnoea and required immediate resuscitation, using what they viewed as the best available treatment, endotracheal intubation and positive pressure ventilation.

Although this new research from the Glasgow team did not explicitly claim hyperbaric oxygen was superior, it attempted to undermine the use of intubation and positive pressure. However, unlike with past attempts, there was no published response to this research and to their claims. Most of the members of the neonatal network, who had spoken out against Hutchison in the past, had by 1968 moved their research on to look at other topics, feeling that issues surrounding newborn resuscitation had been settled to an extent or perhaps felt that the latest publication did not warrant a response. Intubation with positive pressure was also rapidly becoming the preferred method of newborn resuscitation in both Britain and the USA.[1036] Despite hyperbaric oxygen having been advocated for six years,

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Rodger, J., M. Kerr, et al. (1968). "Measurements of oxygen tension in subcutaneous tissues of newborn infants under normobaric and hyperbaric conditions." *Lancet* **2**(7562): 232-236.

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Ibid. p232.

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James, L. S. (1967). "Scientific basis for current perinatal care." *Archives of Disease in Childhood* **42**: 457-466,
Johnson, K. and S. Babson (1967). "Resuscitation of the apneic premature infant." *Pediatrics* **40**(1): 99-100,
Hey, E. and J. Kelly (1968). "Gaseous exchange during endotracheal ventilation for asphyxia a t

it had failed to disseminate beyond Glasgow, and had not gained a strong group of followers. By the late 1960s the neonatal network in Britain was rapidly expanding as the first full-time neonatologists were appointed in universities and hospitals. It would appear that by this time the care of the newborn was being determined by the neonatal network, which had not only gained the support of official bodies, such as the MRC, but which represented a large number of clinicians responsible for newborn care in Britain, and comprised of a number of internationally-recognised specialists in newborn care.

Despite his apparent defeat, Hutchison continued to advocate the use and further investigation of hyperbaric oxygen in his textbook *Practical Paediatric Problems* through to the late 1970s.[1037] However, he was simply one individual and had dwindling weight amongst a widening circle of paediatricians interested in the new sub-specialty of neonatology, not least of all because he was considered a general paediatrician. Neonatology emerged as a specialty heavily linked to clinical science, especially physiology. Hutchison had never fully embraced the importance of basic science in clinical research, and had failed to remain abreast of the rapidly advancing field of neonatal physiology. This in part accounts for the failure of hyperbaric oxygen, as well as the fact that Hutchison was not a member of the neonatal network which was gaining power throughout the 1960s. These factors and others will be discussed in the concluding chapter which analyses the fate of both intragastric oxygen and hyperbaric oxygen and the role of the neonatal network.

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birth." *Journal of Obstetrics and Gynaecology of the British Commonwealth* **75**: 414-,
Neligan, G. (1968). "Correspondence: Resuscitation of the newborn." *Lancet* **2**: 347,
Woody, N. and H. Woody (1968). "Direct digital intratracheal intubation for neonatal resuscitation." *The Journal of Pediatrics* **73**(6): 901-905.
Patterson, J. (1968). "Correspondence: Resuscitation of the newborn." *Lancet* **2**: 347-348,
Barrie, H. (1968a). "Correspondence: Resuscitation of the newborn." *Lancet* **1**: 1033.
Barrie, H. (1968). "Focus on the low birth weight infant. Part 1: Basis of modern management." *Midwife and Health Visitor* **4**: 326-328,
Scott, J. (1968). "Correspondence: Resuscitation of the newborn." *Lancet* **2**: 167,
Behrman, R., L. S. James, et al. (1969). "Treatment of the asphyxiated newborn infant." *The Journal of Pediatrics* **74**(6): 981-988,
Dunn, J. and J. Miller (1969). "Hypothermia combined with positive pressure ventilation in resuscitation of the asphyxiated newborn." *American Journal of Obstetrics and Gynecology* **104**(1): 58-67,
Hull, D. (1969). "Lung expansion and ventilation during resuscitation of asphyxiated newborn infants." *Journal of Pediatrics* **75**: 47-.

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Hutchison, J. H. (1967). *Practical paediatric problems, 2nd edition*. London, Lloyd-Luke Ltd,
Hutchison, J. H. (1972). *Practical paediatric problems, 3rd edition.* London, Lloyd-Luke Ltd,
Hutchison, J. H. (1975). *Practical paediatric problems, 4th edition.* London, Lloyd-Luke Ltd,
Hutchison, J. H. (1980). *Practical paediatric problems, 5th edition.* London, Lloyd-Luke Ltd.

Chapter 8 Discussion and conclusions

A history of newborn resuscitation during the mid-twentieth century

The history of newborn resuscitation which has been presented by practitioner-historians thus far has been simplistic and positivist. It has been suggested by some authors, such as Alex Robertson and Alistair Philip, that prior to the 1950s clinicians took a ‘hands-off’ approach or exhibited a ‘benign neglect’ when it came to newborn resuscitation.[1038] However, as has been demonstrated in chapter 2, the interwar years witnessed a growing interest amongst physiologists and clinicians in the neonate. This resulted in some of the first sustained investigations of fetal and neonatal physiology, such as the work of Joseph Barcorf and Nicholson Eastman, and a new physiological neonate was constructed. The neonate began to be viewed as physiologically distinct from adults and existing in a transitional stage as it moved from life as a fetus to autonomous being.

One result of this physiological research, along with wider social concerns about infant mortality, was the introduction of novel ‘physiologically-informed’ methods of newborn resuscitation, such as Henderson’s inhalatory method and the Drinker respirator, and wider reviews of newborn care. WWII stalled further developments in newborn resuscitation, however analysis of the postwar period illustrates much continuity in practice and research.

Another theme in the history of newborn resuscitation during the early and mid-twentieth century was the involvement of new groups of clinicians, namely paediatricians and anaesthetists. The role of these medical specialists has yet to be discussed in the limited secondary literature. Analysis of the growing involvement of anaesthetists and paediatricians during the interwar years in chapter 3 illustrates the important role that both groups played in the development of newborn resuscitation. Anaesthetists brought with them, from their experience of administering anaesthetics during surgery, the technique of endotracheal intubation, which was soon adapted to resuscitate the asphyxiated newborn.

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Robertson, A. (2003a). "Reflections on errors in neonatology i: The 'hands-off' years, 1920 to 1950." *Journal of Perinatology* **23**: 48-55,
Philip, A. G. S. (2005). "The evolution of neonatology." *Pediatric Research* **58**(4): 799-815.

Equally paediatricians began to develop novel resuscitative techniques and gradually began to relinquish the control of the care of the neonate from the hands of obstetricians. By the post-war period paediatricians had emerged as the dominant clinical voice in debates surrounding newborn resuscitation.

Another very significant theme which has been highlighted throughout was the role of physiologists in the clinical care of the newborn. During the interwar years Joseph Barcroft and Yandell Henderson began to gain a voice in clinical debates. Their research and the research Eastman helped to construct the physiological and pathological neonate, which in turn impacted on the treatment of asphyxia neonatorum. As discussed in chapter 2, the involvement of physiologists in clinical debates and the importance of experimental physiology has been documented by Christopher Lawrence and Steve Sturdy during the same period.[1039] However, the continued authority of experimental physiology and individual researchers, such as Geoffrey Dawes and Kenneth Cross, in the clinical debates over newborn resuscitation after the war, described in chapter 5,6 and 7, may be more unusual. As mentioned, the limited writings on late twentieth-century medical research tend to concentrate on the rapid rise of clinical research, and experimental laboratory-based physiology is noticeably lacking.[1040] The use of clinical research in neonatology was limited by both ethical concerns surrounding experimentation on newborns, as well as technical difficulties, for example the problem of gathering sufficient blood samples for testing blood-gases, which have been mentioned. This may explain the continued use of animal models in research well into the 1960s.

Contrary to the practitioner histories of the development of newborn resuscitation in the mid-twentieth century intubation and positive pressure ventilation did not become the dominant method of newborn resuscitation simply because it ‘worked’,

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Lawrence, C. (1985). “Moderns and ancients: The “new cardiology” in Britain 1880-1930.” *Medical History* **Supp 5**: 1-33.

Sturdy, S. (1992). "From the trenches to the hospitals at home: Physiologists, clinicians and oxygen therapy." in *Medical innovations in historical perspective*. J. Pickstone (Ed.). Houndsmill, Basingstoke, Macmillan Press Ltd**:** 104-123.

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McGehee Harvey, A. (1981). *Science at the Bedside. Clinical research in American medicine 1905-1945*. Baltimore &London, Johns Hopkins University Press
Booth, C. (1987). “Clinical reerach and the MRC” in *Doctors in science and society. Essays of a clinical scientist*. Cambridge, Cambridge University Press: 238-262.
Booth, C. (2003). “From art to science: The story of clinical research”. In *A Physician Reflects: Herman Boerhaave & other essays*. London, Wellcome Trust Centre for the History of Medicine

the development was more complex than the positivist history thus far presented. Chapter 4 examines the plethora of resuscitative methods proposed for newborn resuscitation after WWII, illustrating the lack of consensus in both Britain and America regarding the care of the asphyxiated newborn. It further uncovers the tensions amongst supporters of positive-pressure methods during the interwar years and after WWII, as they debated the use of endotracheal intubation or a face-mask.

As discussed in chapter 5, the growing dominance of endotracheal intubation was as much to do with the informal social network of clinicians concerned with the newborn who constituted the neonatal network during the late 1950s and 1960s, as it did with clinical and physiological research presented to support its use. In fact this was most clearly evident in the fact that the majority of this supportive evidence was produced during the 1960s, thirty years after the technique was first advocated for the resuscitation of newborns.

Similarly intragastric oxygen and hyperbaric oxygen were not just the ‘misadventures’, ‘mistakes’ or ‘deviations’ from the ‘correct’ path, which practitioner-historians have argued. Both techniques played a role in stimulating clinical research into newborn resuscitation, as well as research on neonatal physiology more generally. They helped to highlight the fact that little was known about the ‘normal’ state of the newborn, and that much of the clinical care advocated was not based on a basic understanding of the unique physiology of the newborn and had not, in fact, been scientifically tested.

Both intragastric oxygen and hyperbaric oxygen also highlighted the gap which had emerged between the elite group of clinician-scientists and physiologists, which constituted the neonatal network, and the majority of clinicians responsible for newborn resuscitation. The advocates of the two techniques also called attention to the fact that amongst these non-network clinicians there was still no consensus on the most effective resuscitative technique or an appreciation of the importance and authority of neonatal physiology and animal studies. This realisation prompted the neonatal network to attempt to disseminate the latest neonatal physiology research and to convince the medical community that this research was relevant to newborn care. As well as criticising intragastric oxygen

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Reynolds, L. and E.M. Tansey. (Eds.) (2000). *Clinical Research in Britain, 1950-1980*. London, Wellcome Trust.

and hyperbaric oxygen, the network also attempted to convince the medical community that intubation and positive pressure ventilation was the most effective resuscitative technique for asphyxiated newborns.

As a result the debates which emerged, surrounding the use of intragastric oxygen and hyperbaric oxygen, helped to gather evidence to support the use of intubation and positive pressure ventilation as the most appropriate and effective method of newborn resuscitation. The hyperbaric oxygen controversy specifically united the members of the network against a common enemy, as it were, and cemented the authority of the neonatal network on matters of newborn care, as well as affirming the importance and relevance of physiology in the future improvement of the medical care of the neonate.

Although both intragastric oxygen and hyperbaric oxygen have, to an extent, been written out of the history of newborn care, closer analysis of their fates reveals a much more complex story. Intragastric oxygen received a rapid and widespread rise to popularity in Britain during the 1950s, with the 1958 Perinatal Mortality Survey reporting that 10 in 1000 asphyxiated babies were resuscitated with intragastric oxygen, compared to 1 in 1000 treated with intubation and positive pressure ventilation.[1041] It was not, therefore, an insignificant blip in history as many practitioner-historians would have it. As was outlined in chapter 6, at the time, the majority of clinicians felt both helpless in the treatment of asphyxiated newborns, as well as sceptical about the use of 'dangerous' techniques, such as intubation and positive pressure, and they were concerned by the increasingly technological apparatus suggested for newborn resuscitation, such as ventilators and negative pressure devices. These clinicians viewed intragastric oxygen as a simple, accessible alternative, which could be easily used by both clinicians and midwives. With the lack of any general consensus on the most effective resuscitative technique for newborns during the early 1950s, the dazzling array of new and often complex resuscitative methods suggested, and the lack of any one authoritative voice or group of individuals who claimed responsibility for newborn care, intragastric oxygen was adopted, almost without question, based on the two

1041 [Anon] (1962). "Perinatal mortality." *Lancet* **2**: 1164.

favourable papers published by Åkerrén and Fürstenberg, and Waller and Morris.[1042]

As has been described in chapter 5, towards the end of the 1950s an informal network of individuals concerned with the physiology and care of the newborn had begun to form. This neonatal network consisted of academic clinicians, mainly paediatricians, who had spent time training in basic physiology, and had therefore emerged as a newer breed of clinician-scientists. Other significant members of the network included prominent neonatal physiologists and a number of anaesthetists with an interest in newborn resuscitation. With the apparent popularity of intragastric oxygen, members of the newly formed network began to attack both the lack of physiological explanation supporting intragastric oxygen, as well as the unreliable clinical evidence which had been presented. With the lack of any identifiable supporters of intragastric oxygen by the early 1960s, the onslaught of critical research led to the eventual decline of the technique in Britain by the mid-1960s.

In contrast hyperbaric oxygen was advocated by James Hutchison, Professor of Child Health at the University of Glasgow, and a prominent figure in British Paediatrics during the 1960s. Unlike intragastric oxygen, which was left to disseminate for almost a decade before its use was questioned, hyperbaric oxygen came under immediate attack from Hutchison’s first publication. Again members of the fledgling neonatal network collaborated to undermine Hutchison’s claim, as documented in chapter 7. Although hyperbaric oxygen did not achieve the same widespread dissemination as intragastric oxygen, it remained a major research topic and a point of debate in medical journals, amongst the medical community and with official organisations, including the Ministry of Health and the MRC, for over five years.

It is interesting to examine how hyperbaric oxygen was able, to an extent, to resist the attack from the neonatal network, whereas intragastric oxygen quickly faded out of use when it was questioned. Obviously having James Hutchison, a prominent member of the British paediatric community, as its leading advocate

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1042 Åkerrén, Y. and N. Fürstenberg (1950). "Gastro-intestinal administration of oxygen of asphyxia in the newborn." *Journal of Obstetrics and Gynaecology of the British Empire* **57**(5): 705-713.
Waller, H. and D. Morris (1953). "Resuscitation of the newborn with intragastric oxygen (akerren's method)." *Lancet* **2**: 951-953.

offered a degree of legitimacy to the technique, and on several occasions professional relationships prevented the outright condemnation and dismissal of the technique by those opposed to it. However, another important factor was the lack of any unquestionable evidence which showed both that hyperbaric oxygen was ineffective, but also that intubation and positive pressure ventilation was the best method then available. Whilst both sides of the debate gathered evidence, hyperbaric oxygen remained a prominent issue in the consciousness of those concerned with the care of the newborn, and it even led to the involvement of official bodies, with the MRC attempting to resolve the conflict through a number of conferences.

As a result the hyperbaric oxygen controversy served further to unite the members of the neonatal network, forging stronger collaborative links between the key members from Tizard's clinical unit at the Hammersmith, and Dawes' and Cross' physiology research units in Oxford and at St Mary's. As the controversy unfolded the authority of this informal network was cemented as the MRC called on some of its key members to help resolve the issue. By the end of the 1960s the members of the neonatal network were well established as the leading voices in newborn care.

On a more tangible note the hyperbaric oxygen controversy also helped to push neonatal physiology research forward and helped to standardise newborn resuscitation. Although members of the network had deemed intubation and positive pressure ventilation the best resuscitative treatment, the controversy highlighted that this view was not shared by the majority of clinicians caring for asphyxiated newborns. They also became aware that the majority of clinicians did not possess a sound understanding of the physiology of neonatal asphyxia, and that there was a lack of substantiating physiological and clinical evidence to support their recommendations. As a result members of the neonatal network set about investigating the physiology of asphyxia neonatorum, and defined a two-stage model from animal research, which they found to be comparable to humans. They then continued to conduct controlled animal trials of both hyperbaric oxygen and intubation with positive pressure. With the evidence gathered the network began to convince the medical community of both the value of basic physiology to neonatal care, and also that intubation with positive pressure should be the preferred method. They were therefore not only concerned with dismissing hyperbaric oxygen, but also found that they had to defend and explain their own position on the matter.

The sociologically informed approach to the history of newborn resuscitation

As was stated in chapter 1, this thesis was not intended to be overtly sociological, however my research has been tacitly informed by the sociology of science. Most notably the work of Barry Barnes and David Bloor and the ‘Strong Programme’ in the sociology of scientific knowledge has influenced my approach, and the significance of their work is evident in the preceding discussion, which highlights the importance of social forces in changes in clinical practice and medical knowledge. However, other concepts from the sociology of science also function as useful analytical tools in my research.

As was mentioned in chapter 5, the concept of ‘an invisible college’, taken from the work of Price and Crane, influenced my use of the concept of the ‘neonatal network’.[1043] Price and Crane had focused on the importance of communication in science, which led to the identification of social networks amongst scientists. Price defined the invisible college as:

> [T]he informal affiliation of scientists with common interests who were already strongly embedded in other institutions – indeed, had risen to the upper ranks of those institutions – and whom might live some distance from one another.[1044]

However, the body of work by sociologists during the 1970s and 1980s on invisible colleges focused mainly on bibliometric studies. As Leah Lievrous has stated this led sociologists to focus on:

1043 Price, D. J. D. (1963). *Little science, big science*. New York, Columbia University Press. Crane, D. (1972). *Invisible colleges. Diffusion of knowledge in scientific communities*. Chicago & London, The University of Chicago Press.

1044 Price, D. J. D. (1963). *Little science, big science*. New York, Columbia University Press.

> … formal communication channels among scientists because such channels facilitate the production of documents, which are themselves construed as representations of other informal behaviours.[1045]

Lievrouw argued that their work obscured 'the central role of communication behaviour and interpersonal processes and emphasize[d] the mapping of institutional structures'.[1046] She therefore re-defined the invisible college and it is this definition which is most applicable to my use of the concept of a neonatal network: 'An invisible college is a set of informal communication relations among scientists or other scholars who share a specific common interest or goal.'[1047] However my research goes further by not only exploring the development and action of the neonatal network, but also analysing the content of the network's communication.

The work of Thomas Gieryn on 'Boundary-work' within science is also a useful tool for examining the actions of the neonatal network during the period discussed.[1048] As Gieryn has argued, '"science" is no single thing: its boundaries are drawn and redrawn in flexible, historically changing and sometimes ambiguous ways'.[1049] I would argue that the same is true of medicine, and this is reflected in the resuscitation of the newborn in the twentieth century. During the period discussed there was a gradual shift in how the asphyxiated newborn and the normal newborn were understood by clinicians, which was outlined in the earlier chapters. This in turn contributed to a change in their treatment and how these treatments were determined and tested. The increasing involvement of physiologists in newborn care contributed to the transition from an emphasis on the subjective experience and observations of clinicians, towards the objective more empirically based

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1045 Lievrouw, L. A. (1989). "The invisible college reconsidered. Bibliometrics and the development of scientific communication theory." *Communication Research* **16**(5): 615-628. p619.

1046 Ibid. p620.

1047 Ibid. p622.

1048 Gieryn, T. F. (1983). "Boundary-work and the demarcation of science from non-science: Strains and interests in professional ideologies of scientists." *American Sociological Review* **48**(Dec): 781-795.
Gieryn, T. F. (1999). *Cultural boundaries of science: Credibility on the line*. Chicago, Chicago University Press.

1049 Gieryn, T. F. (1983). "Boundary-work and the demarcation of science from non-science: Strains and interests in professional ideologies of scientists." *American Sociological Review* **48**(Dec): 781-795. p781.

research of physiologists and clinician-scientists, for determining newborn care. These changes met with much resistance, as was evidenced by the debates surrounding newborn resuscitation during the 1950s and 1960s.

As Gieryn has argued:

> [The] construction of a boundary between science and varieties of non-science is useful for scientists' pursuit of professional goals: acquisition of intellectual authority and career opportunities; denial of these resources to "psuedoscientists"; and protection of the autonomy of scientific research from political interference.[1050]

Looking at the actions of the neonatal network this same activity can be viewed. The members of the network had agreed that newborn resuscitation was best achieved using intubation and positive pressure ventilation, and they based this decision on their understanding of newborn physiology and animal studies. When intragastric oxygen and hyperbaric oxygen were suggested as alternative techniques, the members of the network set about drawing boundaries around what they considered to be 'correct', 'reliable', 'objective' and 'scientific' clinical research used to develop and assess the most appropriate resuscitative techniques. The research used to support intragastric oxygen and hyperbaric oxygen was deemed to be outside of these boundaries and was therefore attacked.

As Gieryn has discussed, the construction of these boundaries is multi-functional. It can not only be used to exclude or attack a theory or method which is opposed to the group's research, but it also acts to defend the professional autonomy of scientists when boundary disputes occur.[1051] In the case of newborn resuscitation, the boundary-work of the neonatal network during this dispute acted to both strengthen their authority in matters of newborn care, as well as justify and defend their use of intubation and positive pressure ventilation. This particular boundary dispute contributed to the growing professional authority of members of the neonatal network in newborn care, and also led to a loss of authority for James Hutchison within the neonatal research arena, or as Gieryn would argue:

1050 Ibid. p781.

1051 Ibid.

> When the goal is monopolization of professional authority and resources, boundary-work excludes rivals from within by defining them as outsiders with labels such as “pseudo”, “deviant”, or “amateur”.[1052]

A more recent sociological theory can also be used to examine the eventual rise to power and authority of the neonatal network members. In 2005 the sociologists Scott Frickel and Neil Gross published their General Theory of Scientific/intellectual Movements in the *American Sociological Review,* which incorporated a number of theories from the sociology of ideas, social studies of science, and literature on social movements, including both Gieryn’s ‘Boundary-work’ and the idea of ‘invisible colleges’.[1053] Drawing heavily on the literature on social movements, Frickel and Scott attempted to define a general theory of the social conditions which are most likely to facilitate the formation and success of a scientific/intellectual movement (SIM). If the proponents of intubation, as represented by the neonatal network, are considered to bear some resemblance to a SIM, Frickel and Scott raise some interesting points which contribute to the analysis of my research.

Frickel and Scott define SIMs as ‘collective efforts to pursue research programs or projects for thought in the face of resistance from others in the scientific or intellectual community’.[1054] The definition is further elucidated through a number of assumptions. Although the activities of the neonatal network during the 1950s and 1960s regarding newborn resuscitation do not neatly fit within this framework, it is still sufficiently similar for my discussion. Frickel and Gross argue that the main aim of a SIM is the production and diffusion of knowledge, and that at their core they have a ‘coherent program for scientific and intellectual change or advance’.[1055] This was true of the neonatal network, who by the 1960s considered that the advancement of newborn care was best achieved through animal research and a better understanding of the physiology of fetus and newborn.

1052 Ibid. p792.

1053 Frickel, S. and N. Gross (2005). "A general theory of scientific/intellectual movements." *American Sociological Review* **70**(Apr): 204-232.

1054 Ibid. p206.

1055 Ibid. p206.

The actions of the neonatal network can be viewed as ‘practices that [were] contentious relative to normative expectations’, as defined as a key element of SIMs.[1056] In some respects the members of the network were challenging the authority of the clinician, by basing their claims on animal research and the authority of physiologists. The authority and dominance of the clinician in the resuscitation of the newborn was the norm, and the neonatal network blatantly attacked this. The actions of the network, which ‘challenge[d] received wisdom’ of clinicians, did meet resistance, and did eventually contribute to a ‘break from past practices’, by contributing to the growing authority of the physiologist in the clinic, both of which have been defined as key characteristics of a SIM.[1057] However, the advocacy of intubation and positive pressure was not exactly a challenge to a ‘dominant practice’, but rather a reaction to both a lack of consensus on the most appropriate treatment of the asphyxiated newborn, as well as the threat of what they considered ineffective techniques.

Like Freckel and Gross’ SIM, the actions of the neonatal network were inherently political, in the sense that it aimed to alter the distribution of power, shifting the care of the newborn under the members’ control. As Freckel and Gross argued the aim was to ‘catapult themselves and like-minded others into positions of greater intellectual power and influence’ and to ‘shore up such positions when they are threatened’.[1058] However the network members were not simply careerist in their actions, they all agreed in the intellectual merit of their research and wanted to spread both their research and practices, viewing them as beneficial for the future of newborn care.

The actions of the neonatal network also reflected another relevant characteristic of SIMs, that is the importance of ‘a dissatisfaction’ with a perceived dominant practice, which contributes to their formation.[1059] Although there was no one dominant method of newborn resuscitation used during the mid-twentieth century, the growing popularity of intragastric oxygen and the threat of a similar popularity

1056 Ibid. p207

1057 Ibid. p207.

1058 Ibid. p207.

1059 Ibid. p209.

of hyperbaric oxygen, played an important role in uniting the members of the neonatal network to voice their dissatisfaction, to expand physiological understanding of the newborn and to attempt to standardize newborn resuscitation.

Another key element to the success of a SIM, is the access to key resources, most notably funding, publications and research or teaching positions within universities or laboratories.[1060] All of the key members of the neonatal network had positions within universities or research laboratories, and had secured adequate funding for their research programs, for example both Geoffrey Dawes and Peter Tizard were funded substantially by the Nuffield Trust, and Tizard and Cross were Professors with access to medical students. Both of these factors contributed to the expansion of medical knowledge as well as the dissemination of this knowledge and the chosen resuscitative technique. Having access to specific neonatal physiology laboratories and neonatal research units allowed members to ‘rachet up levels of productivity by allowing for localized information sharing’.[1061] The Neonatal Network further had the informal channels of information flow through the social relationships formed by its members in both America and Britain, which has been described by the work on invisible colleges. All of which contributed to the growing popularity of intubation and positive pressure ventilation, as well as the acceptance of the central role of physiologists in the future improvement of newborn care.

Freckel and Gross’ third proposition argues that ‘the greater a SIM’s access to various micromobilization contexts, the more likely it is to be successful’.[1062] If this is applied to the history of newborn resuscitation it contributes to the understanding of both the eventual popularity of intubation and positive pressure ventilation, as well as the decline of intragastric oxygen and hyperbaric oxygen. Micromobilization contexts, as defined in the literature on social movements, include conferences, symposia, academic laboratories or departments and

1060 Ibid. p213.

1061 Ibid. p217.

1062 Ibid. p219.

societies.[1063] The supporters of intubation and positive pressure ventilation, as represented by the neonatal network had access to a variety of these micromobilization contests, for example the Neonatal Society in Britain, William Windle's Puerto Rico research group, the Harvard and Nuffield one year research fellowships for clinicians, as well as the more institutionally-based Nuffield Research Unit, Oxford, Nuffield Neonatal Research Unit, Hammersmith, and the Neonatal Research Group at UCH. All of which contributed both to the dominance of the intubation and positive pressure by the end of the 1960s, as well as to the emergence of the sub-specialty of neonatology. In contrast the supporters of intragastric oxygen and hyperbaric oxygen lacked a social network of clinicians and scientists, with access to micromobilization contexts, who supported the techniques and could disseminate them. This ultimately led to their gradual fade into obscurity.

Newborn resuscitation and late twentieth-century medicine

Reflecting on the broader narrative of late twentieth century medicine, the history of newborn resuscitation presented here raises some interesting points relating to the wider themes discussed in chapter 1. Firstly the thesis contributes to the writings on the rise of medical science in the twentieth century. Much has been written about the rise of clinical science in the early twentieth century and the resistance it met from the dominant British clinical elite and the tensions felt in individual institutions.[1064] Examples of this literature include Christopher Lawrence

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Ibid. p219. 'Micromobilzation contexts' in the literature of social movements refers to 'local sites in which representatives exert their influence, making the case either explicitly or implicitsly to potential recruits that converting to the movement, and thereby turning their backs on dominant disciplinary frameworks, is intellectually and professionally the right way to proceed'.

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Lawrence, C. and G. Weisz, Eds. (1998). *Greater than the parts, holism in biomedicine, 1920-1950*. New York, OUP.
Lawrence, C. (1985). "Incommunicable knowledge: Science, technology and the clinical art in britain 1850-1914." *Journal of Contemporary History* **20**(4): 503-520,
Sturdy, S. (1992). "From the trenches to the hospitals at home: Physiologists, clinicians and oxygen therapy." in *Medical innovations in historical perspective*. J. Pickstone (Ed.). Houndsmill, Basingstoke, Macmillan Press Ltd**:** 104-123,
Hull, A. (2001). "Hector's house: Sir hector hetherington and the academicization of glasgow hospital medicine before the n.H.S." *Medical History* **45**: 207-242,
Lawrence, C. (2005). *Rockefeller money, the laboratory and medicine in edinburgh 1919-1930. New science in an old country*. Rochester, University of Rochester Press,
Hull, A. (2007). "Teamwork, clinical research, and the development of scientific medicines in interwar britain: The "glasgow school" revisited." *Bulletin of the History of Medicine* **81**: 569-596.

and George Weisz's *Greater than the Parts, Holism in Biomedicine, 1920-1950* and Lawrence's 'Incommunicable Knowledge'. This research and that of others deals mainly with the interwar period and events during the First and Second World Wars. During this period historians, such as Steve Sturdy, Lawrence, and Andrew Hull, have described how the methods and practice of medical science were gradually adopted by clinicians and institutions during the interwar years. However, many of the themes and trends that these writings discuss are also reflected in the history of newborn resuscitation after the War.

The history of newborn resuscitation in the mid-twentieth century documents the intimate relationship which was developing between the basic sciences and medicine. It reflects the successful partnerships which were cultivated between scientists and clinicians, as well as illustrating how clinicians began to adopt both the language of science and its methods in the clinic. The thesis also reflects on the problems and tensions that this new relationship caused. Importantly the thesis analyses the neglected post-war period, and shows that the relationship between science and medicine remained problematic and complex. This is contrary to claims that the war had cemented the position of science in medicine and quelled the resistance amongst the British medical community.

There are a number of ways that the growing authority of basic sciences can be illustrated. It is very evident from the preceding chapters that there was a growing trend of doctors referring to advances in fetal and neonatal physiology in their discussions of newborn care. From the interwar years the work of Joseph Barcroft was used to support new techniques and critique other resuscitative methods, as was the work of Geoffrey Dawes and Kenneth Cross in the 1950s and 1960s. However, the research of these physiologists was not only read by clinicians, but individual physiologists also began to gain a voice in debates over the clinical care of the newborn. This increasing involvement of neonatal physiologists in clinical debates over newborn resuscitation and their growing authority is very evident in chapters 6 and 7 which discussed the fate of both intragastric oxygen and hyperbaric oxygen.

As discussed the role of physiologists in clinical research and practice has been discussed by Lawrence and Sturdy, on their work on the interwar period. However, writings on later twentieth-century have not documented similar interactions continuing after the war. The case of neonatology research during the 1950s and

1960s, with the continued involvement of physiologists and authority of experimental physiology research, could be unusual. Clearly further historical analysis of later twentieth-century medicine is needed to examine this.

The increasingly scientific nature of medicine is also reflected in the new breed of ‘clinician-scientist’ which emerged from the interwar years. Other historians, such as Andrew Hull, Malcolm Nicolson and David Smith, have discussed the emergence of this ‘intermediate position’, which describes ‘practitioners who combined a strong interest in laboratory science with a continuing commitment to clinical control of both practice and research’.[1065] This same trend is evident in my discussions of the new breed of paediatricians who emerged after the war in chapter 5. However, unlike the interwar clinician-scientists described by these previous authors, who had strived to maintain control of clinical research and practice, these post-war clinician-scientists had begun to relinquish some of their authority and control to neonatal physiologists. Prime examples of these post-war clinician-scientists include Peter Tizard and John Davis, who both worked alongside physiologists, such as Cross and Dawes, and respected the authority and contribution of these physiologists to clinical matters.

With wider recognition of the importance of research training in medical education, especially postgraduate education, which was reflected in the establishment of the Royal Postgraduate Medical School, Hammersmith.[1066] In the post-war years this trend towards basic scientific research training was facilitated by a series of research fellowships, such as the Rockefeller, Nuffield and Harvard Research Fellowships discussed in chapter 5, which had allowed a number of both British and American paediatricians to spend up to a year conducting basic research in fetal and neonatal physiology. These fellowships further strengthened the relationship between physiology and medical care of the newborn, as well as

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Hull, A. (2007). "Teamwork, clinical research, and the development of scientific medicines in interwar britain: The "glasgow school" revisited." *Bulletin of the History of Medicine* **81**: 569-596. p575. The concept of the clinician-scientist was first described in a paper by Nicolson, M. and Smith, D. (1997). ‘Science and Clinical Scepticism: The Case of Ralph Stockman and the Glasgow Medical Faculty’. Presented at Science and Technology Dynamics Internal Progress Conference, Amsterdam, September.

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Booth, C. (1985). "Medical science and technology at the royal postgraduate medical school: The first 50 years." *BMJ* **291**: 1771-1779,
Reynolds, L. and E. M. Tansey, Eds. (2000). *Clinical research in britain, 1950–1980*. London, Wellcome Trust,
Booth, C. (2003). "From art to science: The story of clinical research". in *A physician reflects: Herman boerhaave & other essays*(Ed.). London, Wellcome Trust.

equipping paediatricians with relevant scientific research skills and effectively indoctrinating them into the new clinical science.

Each of these trends show continuity with writings on the interwar years and illustrate that clinicians were still adapting to and attempting to incorporate science in medicine after the War and that contrary to many historical writings the war had not fully cemented its position in medical culture.

Another theme, which has been discussed in writings on the interwar years, is the growing tensions that the rise of medical science caused. As has been discussed in chapter 1 many clinicians resisted the growing dominance of science in medicine, resisting both the associated reductionism, the use of scientific research methods and challenging the authority of scientists in clinical matters. This same theme has been illustrated in the debates surrounding newborn resuscitation after the War. It is clear that clinicians continued to struggle with these same tensions as they attempted to balance their dual role of healer and scientist. This struggle is most evident in the case of James Hutchison, as described in chapter 7. Hutchison struggled to stay apace of the rapidly advancing understanding of neonatal physiology and he resisted the growing authority of physiological research over his own clinical judgements when assessing resuscitative techniques.

Hutchison also struggled with the ethics of the new requirements of clinical research, reflected in his initial resistance to a controlled trial of both hyperbaric oxygen and intubation with positive pressure ventilation. Again this tensions reflects wider concerns in late twentieth-century medicine. Throughout the period the ethics of clinical trials of resuscitative techniques were continually raised. Individuals argued that it was unethical to use a treatment unless it was properly tested on animals or through a controlled clinical trial, whereas others argued that the mounting of a controlled clinical trial was itself unethical as it would deny some babies a life-saving treatment. This feeds into the wider narrative of growing critique of biomedicine during the 1950s and 1960s.[1067]

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Nye, R. (2003). "The evolution of the concept of medicalization in the late twentieth century." *Journal of the History of the Behavioural Sciences* **39**: 115-129.
Faden, R. and T. Beauchamp (1986). *A history and theory of informed consent*. New York, OUP,
Rothman, D. (1991). *Strangers at the bedside*. New York, Basic Books,
Cooter, R. (2003). "The ethical body". in *Companion to medicine in the twentieth century*. R.

A further characteristic of twentieth-century medicine noted by historians was a trend towards super-specialization. The history of newborn resuscitation is set within the wider narrative of the development of the sub-specialty of neonatology, which emerged during the latter half of the twentieth century. In Britain the first tangible evidence of this novel sub-specialty can be seen in the establishment of the Neonatal Society in 1959, when it was decided that the British Paediatric Association and the Physiological Society no longer catered for the special interests of a growing group of individual researchers. The move towards specialization historically has met with much resistance from members of the medical community, which again was reflected in the debates surrounding newborn resuscitation after the War. [1068]

In conclusion this research contributes to the more recent writings on the rise of medical science, such as those of Sturdy and Hull, which suggest that it was more complex and varied than once thought. These authors describe the emergence of variety of different types of clinical and more generally medical science in the twentieth century, each unique to its local circumstances. The history of newborn resuscitation reflects this same variation, with successful and intimate research partnerships and networks developing between paediatricians and physiologists in some areas, such as at the Hammersmith and Oxford. Whereas in other locations individual clinicians or small groups of clinicians attempted to conduct their own form of medical research without the aid of basic scientists, which was informed by their knowledge of physiology and their own interpretation of scientific research methods, such as Hutchison in Glasgow and the proponents of intragastric oxygen.

This thesis illustrates that, despite the success of physiologists during both World Wars, and the status this afforded them, their involvement in medical research and care was not universally welcomed or unproblematic during the mid-twentieth century.[1069] The thesis also reflects on the impact the new medical science had on

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Cooter and J. Pickstone (Ed.). London, Routledge: 451-468,
Jenner, M. S. R. and B. O. Taithe (2003). "The historiographical body". in *Companion to medicine in the twentieth century*. R. Cooter and J. Pickstone (Ed.). London, Routledge.

1068

Lawrence, C. and G. Weisz, Eds. (1998). *Greater than the parts, holism in biomedicine, 1920-1950*. New York, OUP,
Weisz, G. (2006). *Divide and conquer: A comparative history of medical specialization*. New York, OUP.

1069

Sturdy, S. (1992). "From the trenches to the hospitals at home: Physiologists, clinicians and the post-war clinicians. Academic clinicians were expected to command a dual role of both clinician and researcher after the war. Some clearly embraced this divided responsibility and flourished in their new laboratory and clinical surroundings, whereas others, such as Hutchison, failed to adapt and to embrace basic animal research and cutting age clinical science, feeling more comfortable in the clinic. This divided role presented many tensions for the post-war clinician.

Although the history of newborn resuscitation I have presented showed continuity with developments in the interwar years, perhaps more interesting are the contrasts with this earlier period. During the 1950s and 1960s clinicians who made up the neonatal network had begun to relinquish control over medical research and practice by allowing physiologists to have some authority over these matters. This was in contrast to their predecessors the clinician-scientists of the interwar years. This shift is significant as it not only challenged the authority of the clinician in matters of clinical care, but shows a type of medicine more reflective of later twentieth-century biomedicine. Biomedicine is characterised by the authority afforded scientific research and the scientific understanding of the body and disease, as well as the central role given to scientists in the medical care of patients, from the understanding of disease progression, physiological function and diagnosis through to treatment and monitoring of patients. As was discussed in chapter 1 there is an apparent reluctance amongst historians to tackle later twentieth-century biomedicine, but perhaps, as this thesis illustrates, this work can begin by more detailed study of the decades after the end of World War II which reflect the transition towards the current state of biomedicine.

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oxygen therapy." in *Medical innovations in historical perspective*. J. Pickstone (Ed.). Houndsmill, Basingstoke, Macmillan Press Ltd**:** 104-123.

Appendix 1.

The results of Schmidt *et al*'s 1954 survey of newborn resuscitation practices in 168 Canadian hospitals. Taken from Schmidt, O et al (1956) 'An Evaluation of Infant Resuscitation', *Canadian Medical Association Journal*, v75, p503-506.

Question 1.—Does your department have a set scheme of infant resuscitation?

Number of hospitals	*Answer*
37	Yes
23	No
1	More or less
Winnipeg	Yes—drawn up by the Resuscitation Committee

Question 2.—What is your deciding factor for commencing resuscitation?

Number of hospitals	*Deciding factor*
25	Apnœa
14	Respiration
13	Attending physician's clinical judgment
4	Fetal distress
2	When required
1	Fetal heart rate below 100 or irregular
1	Failure to respond to stimuli
1	Delivery
Winnipeg	Apnœa or irregularity of respiration lasting one minute after birth

Question 3.—When do you commence resuscitation?

Number of hospitals	*Commencement*
13	Immediately
11	After apnœa lasting 1-3 minutes
11	After an interval of 1-3 minutes
9	At attending physician's clinical judgment
7	After apnœa and pharyngeal suction
4	After asphyxia
2	If fetal heart rate is below 100 or irregular
2	Not stated
2	When required
Winnipeg	Always within three minutes after birth

Question 4.—What machines and methods are used?

Number of hospitals	*Machines*
16	Kreiselman resuscitator[1]
15	Ericson and Johnson resuscitator[2]
5	Flagg resuscitator[3]
5	Emerson resuscitator
5	Bloxsom air lock[4]
5	None
4	Mask and oxygen bag with hand control
3	Rocking-bed[5] or Rockette
1	Mann resuscitator[6]
1	Goddard-Bennett-Lovelace infant hand resuscitator

Continued on next page.

1	To-and-fro Forregger with hand control
19	Two or more of the above machines
Winnipeg	Kreiselman, E. and J., Cherniack automatic resuscitator[8] rocking-bed, electrophrenic respirator,[9] infant-size Drinker respirator[10]

Number of hospitals	*Methods*
43	Oxygen and endotracheal tube if necessary[11]
8	Endotracheal tube and operator's mouth to tube resuscitation
5	Manual artificial respiration
4	Stimulants—caffeine, alpha-lobeline,[13] nalline[14]
3	Carbon dioxide[15]
1	External stimulation only
Winnipeg	Oxygen with pressure and endotracheal tube if necessary Nalline is the only stimulant recommended.

Question 5.—Who is in charge of resuscitation?

Number of hospitals	*Answer*
21	Attending physician
11	Anæsthetist
9	Attending physician and anæsthetist
8	Resident interns
3	Everybody and anybody
2	Pædiatrician
2	Registered nurse
2	Attending physician and pædiatrician
2	Not stated
1	Anæsthetist and pædiatrician
Winnipeg	The attending physician delegates the responsibility to the anæsthetist and pædiatrician.

Question 6.—What classification of asphyxia do you use?

Number of hospitals	*Classification*
25	None or not stated
18	Flagg's classification[16]
9	Mild-moderate-severe
2	General classification
2	According to cause of asphyxia
2	Central and peripheral
1	Primary and secondary
1	According to time
1	Apgar rating[17]
Winnipeg	Uses Apgar rating plus a modification.

Question 7.—Is your department satisfied with the methods of resuscitation and classification of asphyxia?

Number of hospitals	*Answer*
35	Yes
17	No
5	Not stated
4	More or less
Winnipeg	Our answer is yes in the light of present knowledge, but we are constantly trying to improve both the methods and classification

Bibliography

Primary Sources

Interviews and Correspondence

McAdams, R. (2007). Interview with Dr Edmund Hey and Professor Sam Richmond, 20th November.

McAdams, R. (2007). Interview with Dr Herbert Barrie, 31st January.

McAdams, R. (2007). Interview with Professor Alec Campbell and Professor Mike Tunstall, 27th August.

McAdams, R. (2007). Interview with Professor Forrester Cockburn, 26th March.

McAdams, R. (2007). Interview with Professor John A Davis, 5th June.

McAdams, R. (2007). Interview with Professor John Forfar, 19th June.

McAdams, R. (2005). Interview with Professor Dan Young, November.

Hull, D. (2007). Email Correspondence 'Neonatal Resuscitation' with R. McAdams.

Archival Sources

Archives of the Medical Research Council, *National Archives,* London.

Archives of the Ministry of Health, *National Archives*, London.

Archives of the Neonatal Society, *Archives and Manuscripts, Wellcome Trust Library, London.*

Archives of the National Birthday Trust*, Archives and Manuscripts, Wellcome Trust Library,* London.

Papers of the Standing Medical Advisory Committee (Scotland) Oxygen Therapy Sub-committee, *Archives of the Scottish Home and Health Department*, Edinburgh.

Papers of the Committee on Infant Mortality from 1958-1964, *Archives of the New York Academy of Medicine, New York*.

Official Publications

[Anon] (1943). *Infant Mortality in Scotland. A Report of a Sub-Committee of the Scientific Advisory Committee*. Edinburgh, HMSO.

[Anon] (1961). *Report of the Sub-Committee on the Prevention of Prematurity and the Care of Premature Infants. Ministry of Health Central Health Services Council.* London, HMSO.

Published primary sources

[Anon] (1931). "New York Obstetrical Society. Meeting of December 9, 1930." *American Journal of Obstetrics and Gynecology* **31**: 599-603.

[Anon] (1932). "Annotation: Asphyxia neonatorum." *Lancet* **1**: 411.

[Anon] (1934). *The Proceedings of the Sixth Northern Pediatric Congress, Stockholm, Aug 27th-29th, 1934*, Acta Paediatricia v17 supplement 1 1935.

[Anon] (1935). "Treatment of asphyxia neonatorum." *Lancet* **1**: 751-752.

[Anon] (1937). "Annotations: The treatment of asphyxia neonatorum."*Lancet* **1**: 995-996.

[Anon] (1937). "Reports of Societies: Royal Society of Medicine (Section of Obstetric and Gynaecology.)." *BJOG: An International Journal of Obstetrics and Gynaecology* **44**(3): 594-597.

[Anon] (1938). "Babies who do not breathe." *Lancet* **2**: 731.

[Anon] (1939). "Leading article: Respiration in utero." *Lancet* **2**: 838.

[Anon] (1941). "Treatment of asphyxia neonatorum." *Lancet* **1**: 355-356.

[Anon] (1950). "Discussion on resuscitation of the newborn." *Proceedings of the Royal Society of Medicine* **43**(6): 443-452.

[Anon] (1956). "Resuscitation of newborn infants. A Report by the Special Committee on Infant Mortality of the Medical Society of the County of New York." *Obstetrics and Gynecology* **8**(3): 336-363.

[Anon] (1957). "Archiater to preemies." *Time*: 11th Nov.

[Anon] (1962). "Perinatal mortality." *Lancet* **2**: 1164.

Abramson, H. (1960). *Resuscitation of the Newborn Infant: Principles and Practice*. St Louis, The CV Mosby Company.

Abramson, H. (1966). *Resuscitation of the Newborn Infant and Related Emergency Procedures*. St Louis, The CV Mosby Company.

Acheson, G., Dawes, G.S. and Mott, J.C. (1957). "Oxygen consumption and the arterial oxygen saturation in foetal and new-born lambs." *Journal of Physiology* **135**: 623-642.

Adair, G., J. Barcroft, Barron, D.H., Goodman, E.N., Hall, F.G., Hayasi, K., O'Brien, A., Pace, J.F. and Phillips, A.E. (1936). "The oxygen content of the blood in the carotid and umbilical arteries of the foetal sheep." *Journal of Physiology* **87**: P37.

Åkerrén, Y. (1954). "[Asphyxia, shock and gastrointestinal oxygen therapy in the newborn]." *Nordic Medicine* **52**(51): 1759-1759.

Åkerrén, Y. (1954). "A simple device for oxygen therapy of infants particularly in asphyxia neonatorum." *An International Journal of Obstetrics and Gynaecology* **61**(4): 477-479.

Åkerrén, Y. and N. Fürstenberg (1950). "Gastro-intestinal administration of oxygen of asphyxia in the newborn." *Journal of Obstetrics and Gynaecology of the British Empire* **57**(5): 705-713.

Apgar, V. (1953). "Proposal for a new method of evaluation of the newborn infant." *Current Researches in Anesthesia and Analgesia* **32**: 260.

Apgar, V. and J. Kreiselman (1953). "Studies on resuscitation. An experimental evaluation of the Bloxsom air lock." *American Journal of Obstetrics and Gynecology* **65**(1): 45-52.

Ardan, G., G. Dawes, Prichard, M.M.L., Reynolds, S.R.M. and Wyatt, DG (1952). "The effect of ventilation of the foetal lungs upon the pulmonary circulation." *Journal of Physiology* **118**: 12-22.

Baar, H. (1946). "The post-mortem examination of the newborn infant." *British Medical Bulletin* **4**: 178-188.

Baird, D. and Walker, J. (1954). "The causes and prevention of stillbirths and first week deaths." *The Journal of Obstetrics and Gynaecology of the British Empire* **61**(4): 433-448.

Barclay, A., J. Barcroft, Barron, D.H. and Franklin, K.J. (1938). "X-ray studies of the closing of the ductus arteriosus." *British Journal of Radiology* **11**: 570-585.

Barcroft, J. (1914). *The Respiratory Function of the Blood*. Cambridge, Cambridge University Press.

Barcroft, J. (1933). "The conditions of foetal respiration." *Lancet* **2**: 1021-1024.

Barcroft, J. (1936). "Fetal circulation and respiration." *Physiological Review* **16**: 103-128.

Barcroft, J., Barron, D., Kramer, K. and Millikan, G.A. (1937). "The effect of urethane on the onset of respiration at birth." *Journal of Physiology* **90**: P29.

Barcroft, J. (1939). "The intra-uterine development of respiratory effort." *BMJ* **ii**: 986-987.

Barcroft, J. (1941). "Four phases of birth." *Lancet* **2**: 91-95.

Barcroft, J. (1942). "The onset of respiration at birth." *Lancet* **2**: 117-120.

Barcroft, J. (1946). *Researches on Pre-Natal Life*. Oxford, Blackwell Scientific Publications.

Barcroft, J. and D. Barron (1936). "The genesis of respiratory movements in the foetus of the sheep." *Journal of Physiology* **88**: 56-61.

Barcroft, J., Barron, D. and Matthews, B.H.C. (1936). "The genesis of respiratory movements in the sheep." *Journal of Physiology* **86**: 29.

Barcroft, J., Barron, D., Cowie, A.T., Forsham, P.H. and MacDonald, A. (1939). "The effect of asphyxia on inhibition of respiratory movement in the sheep's foetus." *Journal of Physiology* **96**: 12-13.

Barcroft, J., Barron, D., Cowie, A.T. and Forsham, P.H. (1940). "The oxygen supply of the foetal brain of sheep and the effect of asphyxia on foetal respiratory movement." *Journal of Physiology* **97**: 338-346.

Barcroft, J. and M. Mason (1938). "The atmosphere in which the foetus lives." *Journal of Physiology* **93**: 21-22.

Barnett, T. and J. Foley, (Eds.) (1963). *The Obstetrician, Anaesthetist and the Paediatrician in the Management of Obstetric Problems. Transactions of the South-Western Obstetrical and Gynaecological Society's Autumn Meeting Held at Portsmouth 7-10 November 1961.* Oxford, Pergamon Press.

Barrie, H. (1959). "Letter to the editor: Intragastric administration of oxygen." *Lancet* **1**: 884-885.

Barrie, H. (1962a). "The Apgar evaluation of the newborn infant." *Developmental Medicine and Child Neurology* **4**(2): 128-132.

Barrie, H. (1962b). "Respiratory stimulants in the newborn." *Lancet* **2**: 742-746.

Barrie, H. (1963). "Hyperbaric oxygen in resuscitation of the newborn." *Lancet* **2**: 1223-1224.

Barrie, H. (1963). "Resuscitation of the newborn." *Lancet* **2**: 650-655.

Barrie, H. (1968a). "Correspondence: Resuscitation of the newborn." *Lancet* **1**: 1033.

Barrie, H. (1968b). "Focus on the low birth weight infant. Part 1: Basis of modern management." *Midwife and Health Visitor* **4**: 326-328.

Barrie, H. and D. Barrie (1965). "Correspondence: Death by suction." *Lancet* **1**: 962.

Barrie, H. and R. Bonham-Carter (1959). "Correspondence: Respiratory difficulties at birth." *BMJ*: 1183-1184.

Barrie, H. and G. Miller (1966). "Blood-gas tensions during apnoea in hyperbaric oxygen." *Lancet* **2**: 1394-1396.

Barton, E. (1915). “The condition of the larynx and trachea in the stillborn infant and its bearing on artificial respiration.” *The Journal of Obstetrics and Gynaecology of the British Empire* **27**: 138-40.

Belfrage, D. (1938). "Correspondence: Asphyxia neonatorum." *Lancet* **2**: 856-857.

Behrman, R., L. S. James, et al. (1969). "Treatment of the asphyxiated newborn infant." *The Journal of Pediatrics* **74**(6): 981-988.

Blaikley, L. and G. Gibberd (1935). "Asphyxia neonatorum: It's treatment by tracheal intubation." *Lancet* **1**: 736-739.

Bloxsom, A. (1942). "The difficulty in beginning respiration seen in infants delivered by cesarean section." *Journal of Pediatrics* **20**: 215-222.

Bloxsom, A. (1950). "Resuscitation of the newborn infant: Use of the positive pressure oxygen-air lock." *Journal of Pediatrics* **37**: 311-319.

Bloxsom, A. (1951). "Asphyxia neonatorum: A new method of resuscitation." *JAMA* **146**(12): 1120-1124.

Boerema, I. (1960). "Life without blood." *Journal of Cardiovascular Surgery* **1**: 133-146.

Born, G., G. Dawes, et al. (1955). "The relief of central cyanosis caused by pulmonary arterio-venous shunts by constriction of an arterial ductus arteriosus." *Journal of Physiology* **130**: 167-190.

Brothers, A. (1896). *Infantile Mortality During Childbirth and Its Prevention*. Philadelphia, P Blaikston, Son & Co.

Bullough, J. (1958). "Protracted foetal and neonatal asphyxia." *Lancet* **1**: 999-1000.

Butler, N. (1963). "Complications of birth asphyxia with special reference to resuscitation". *The Obstetrician, Anaesthetist and Obstetrician in the Management of Obstetric Problems. Transactions of the South-Western Obstetrical and Gynaecological Society's Autumn Meeting Held at Portsmouth 7-10 November 1961.* T. Barnett and J. Foley. Oxford, Pergamon**:** 133-140.

Butler, N. and D. Bonham (1963). *Perinatal Mortality. The First Report of the 1958 British Perinatal Mortality Survey under the Auspices of the National Birthday Trust Fund.* Edinburgh and London, E & S Livingstone Ltd.

Cameron, S., Hewitt, J., Lennie, R.A. and Morton, E.D. (1939). *A Glasgow Manual of Obstetrics*, 3rd Edition. Glasgow, University of Glasgow.

Campbell, A. G. M., Cross, K.W., Dawes, G.S. and Hyman, A.I. (1966). "A comparison of air and oxygen in a hyperbaric chamber or by positive pressure ventilation, in the resuscitation of newborn rabbits." *Journal of Pediatrics* **68**(2): 153-163.

Cappe, B. and I. Pallin (1951). "Practical aspects of resuscitation of the newborn." *New York Journal of Medicine* **51**: 1797-1800.

Cook, C., Lucey, J., Drorbaugh, J.E., Segal, S., Sutherland, J.M. and Smith, C.A. (1956a). "Medical progress: apnea and respiratory distress in the newborn infant. physiologic background, resuscitation and supportive technics." *NEJM* **254**(12): 562-568.

Cook, C., Lucey, J., Drorbaugh, J.E., Segal, S., Sutherland, J.M. and Smith, C.A. (1956b). "Medical progress: apnea and respiratory distress in the newborn infant. physiologic background, resuscitation and supportive technics." *NEJM* **254**(13): 604-610.

Cook, C., Lucey, J., Drorbaugh, J.E., Segal, S., Sutherland, J.M. and Smith, C.A. (1956c). "Medical progress: apnea and respiratory distress in the newborn infant. physiologic background, resuscitation and supportive technics." *NEJM* **254**(14): 651-657.

Cook, C. (1966). "Treatment of respiratory failure of newborn infants." *Journal of Pediatrics* **68**(2): 327.

Cook, C., Barrie, H. and Avery, M.E. (1960). "Respiration and respiratory problems of the newborn infant." *Advances in Pediatrics* **11**: 11-80.

Cooper, E. A., Smith, H. and Pask, E.A. (1960). "On the efficiency of intragastric oxygen." *Anaesthesia* **15**(3): 211-228.

Cope, E. (1952). "British Congress of Obstetrics and Gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 673-676.

Corner, B. (1952). "British Congress of Obstetrics and Gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 670-673.

Coryllos, P. (1931). "Atelectasis, asphyxia and resuscitation in the newborn." *American Journal of Obstetrics and Gynecology* **21**: 512-525.

Coxon, R. V. (1960). "The effect of intragastric oxygen on the oxygenation of arterial and portal blood in hypoxic animals." *Lancet* **1**: 1315-1317.

Cross, K. (1966). "Resuscitation of the asphyxiated infant." *British Medical Bulletin* **22**(1): 73-78.

Cross, K.W., Dawes, G.S. and Mott, J.C. (1959). "Anoxia, oxygen consumption and cardiac output in new-born lambs and adult sheep." *Journal of Physiology* **146**: 316-343.

Cross, K.W., Dawes, G.S., Hyman, A.I. and Mott, J.C. (1964). "Preliminary Communication: Hyperbaric Oxygen and Intermittent Positive-Pressure Ventilation in Resuscitation of Asphyxiated Newborn Rabbits." *Lancet* **2**: 560-522.

Cross, K., Hooper, J. and Oppe, T.E. (1953). "The effect of inhalation of carbon dioxide in air on the respiration of the full-term and premature infant." *Journal of Physiology* **122**: 264-273.

Cross, K.W., Hooper, J.M.D. and Lord, J.M. (1954). "Anoxic depression of the medulla in the new-born infant." *Journal of Physiology* **125**: 628-640.

Cross, K.W., Killick, E.M. and Huggett, A St. George (1954). "Hypoxia in fetal and neonatal life." *American Journal of Obstetrics and Gynecology* **68**(1): 81-90.

Cross, K. and T. Oppé (1952). "The effect of inhalation of high and low concentrations of oxygen on the respiration of the premature infant." *Journal of Physiology* **117**: 258-291.

Cross, K. and T. Oppé (1952). "The respiratory rate and volume in the premature infant." *Journal of Physiology* **116**: 168-174.

Cross, K. W. and P. W. Roberts (1951). "Asphyxia neonatorum treated by electrical stimulation of the phrenic nerve." *BMJ*: 1043-1048.

Cross, K.W., Tizard, J.P.M. and Trythall, D.A.H. (1955). "The metabolism of new-born infants breathing 15% oxygen." *Journal of Physiology* **129**: 69-70.

Cross, K. and P. Warner (1951). "The effect of inhalation of high and low oxygen concentrations on the respiration of the newborn infant." *Journal of Physiology* **114**: 283-295.

Davis, E. (1904). *Obstetric and Gynecologic Nursing*. New York & London, WB Saunders & Company.

Davis, J.A. and J.P.M. Tizard (1961). "Practical problems of neonatal paediatrics considered in relation to animal physiology." *British Medical Bulletin* **17**(2): 168-173.

Davis, J. A. and J. P. M. Tizard (1964). "Hyperbaric oxygen in resuscitation of the newborn." *Lancet* **1**: 166.

Dawes, G. and J. Mott (1959). "Reflex respiratory activity in the new-born rabbit." *Journal of Physiology* **145**: 85-97.

Dawes, G.S., Mott, J.C., Widdicombe, J.G. and Wyatt, D.G. (1953). "Changes in the lungs of the new-born lamb." *Journal of Physiology* **121**: 141-162.

Dawes, G.S., Mott, J.C., and Widdicombe, J.G. (1954). "The foetal circulation in the lamb." *Journal of Physiology* **126**: 563-587.

Dawes, G.S., Mott, J.C. and Shelly, H.J. (1959). "The importance of cardiac glycogen for the maintenance of life in foetal lambs and new-born animals during anoxia." *Journal of Physiology* **146**: 516-538.

Day, R., Goodfellow, A., Apgar, V. and Beck, G.J. (1952). "Pressure-time relationship in the safe correction of atelectasis in animal lungs." *Pediatrics, Springfield* **10**: 593-597.

Day, R. (1955). "Expansion of the lungs of newborn infants." *JAMA* **159**(14): 1340-1341.

DeLee, J. (1913). *The Principles and Practice of Obstetrics*. Philadelphia & London, WB Saunders & Company.

DeLee, J. and J. Greenhill (1943). *Principles and Practice of Obstetrics, 8th Edition*. Philadelphia & London, WB Saunders and Co.

DeLee, J. and J. Greenhill (1947). *Principles and Practice of Obstetrics 9^th^ edition*. Philadelphia & London, WB Saunders Ltd.

Dillon, J. (1942). "The respiratory function of the digestive tract as the basis of roentgenographic life test." *American Journal of Roentgenology* **48**(5): 613-624.

Donald, I. (1954). "Atelectasis neonatorum." *The Journal of Obstetrics and Gynaecology of the British Empire* **61**(6): 725-737.

Donald, I. (1960). "Asphyxia neonatorum." *British Journal of Anaesthesia* **32**: 106-115.

Donald, I. (1963). "Asphyxia neonatorum - the obstetrician's viewpoint". *The Obstetrician, Anaesthetist and Obstetrician in the Management of Obstetric Problems. Transactions of the South-Western Obstetrical and Gynaecological Society's Autumn Meeting Held at Portsmouth 7-10 November 1961.* T. Barnett and J. Foley. Oxford, Pergamon**:** 109-124.

Douglas, J. (1951). "Health and survival of infants in different social classes." *Lancet* **2**: 440.

Drillien, C. (1947a). "Studies in prematurity, stillbirth and neonatal death. Part I Factors affecting birth-weight and outcome." *Journal of Obstetrics and Gynaecology* **54**: 300-323.

Drillien, C. (1947b). "Studies in prematurity, stillbirth and neonatal death.Part II. Delivery and its hazards." *The Journal of Obstetrics and Gynaecology of the British Empire* **54**: 443-468.

Drinker, P. and C. McKhann (1929). "The use of a new apparatus for the prolonged administration of artificial respiration." *JAMA* **92**(20): 1658-1660.

Dunn, J. and J. Miller (1969). "Hypothermia combined with positive pressure ventilation in resuscitation of the asphyxiated newborn." *American Journal of Obstetrics and Gynecology* **104**(1): 58-67.

Eastman, N. (1930). "Fetal blood studies I. The oxygen relationship of umbilical cord blood and birth." *Bulletin of the Johns Hopkins Hospital* **47**(4): 221-230.

Eastman, N. (1931). "Fetal blood studies I.I. The lactic acid content of umbilical cord blood under various conditions." *Bulletin of the Johns Hopkins Hospital* **48**: 261-268.

Eastman, N. (1932). "Foetal blood studies I.I.I.The chemical nature of asphyxia neonatorum and its bearing on certain practical problems." *Bulletin of the Johns Hopkins Hospital* **50**(1): 39-50.

Eastman, N. (1936). "Foetal blood studies V. The role of anesthesia in the production of asphyxia neonatorum." *American Journal of Obstetrics and Gynecology* **31**(4): 563-572.

Eastman, N.J., Ceiling, E.M.K. and De Lawder, A.M. (1933). "Foetal blood studies I.V. The oxygen and carbon dioxide dissociation curves of foetal blood." *Bulletin of the Johns Hopkins Hospital* **53**(5): 246-254.

Eve, F. (1933). "Actuation of the inert diaphragm by a gravity method." *Lancet* **1**: 995-997.

Eve, F. and N. Forsyth (1948). "Asphyxia of the newborn treated by rocking." *BMJ*: 554-555.

Fazekas, J.F., Alexander, F.A.D. and Himwich, H.E. (1941). "Tolerance of the newborn to anoxia." *American Journal of Physiology* **134**: 281-287.

Flagg, P. (1927). "Intratracheal inhalation." *Archives of Otolaryngology* **5**: 394-399.

Flagg, P. (1928). "The treatment of asphyxia in the newborn." *JAMA* **91**: 788-791.

Fletcher, J. and J. Rogers (1951). "Resuscitation of the newborn." *JAMA* **145**(8): 533-538.

Fleury, J. (1953). "Oxygen treatment via stomach for anoxia." *Nourisson* **41**: 141-143.

Fox, T. F. (1960). "Annotation: Intragastric oxygen." *Lancet* **2**: 1129-1130.

Gairdner, D., (Ed.) (1954). *Recent Advances in Paediatrics*. London, J & A Churchill.

Galos, G. and S. Surks (1957). "Cardiorespiratory arrest in the newborn treated by cardiac massage." *American Journal of Obstetrics and Gynecology* **74**(5): 1108-1111.

Gaisford, W. (1952a). "British Congress of Obstetrics and Gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 663-666.

Gaisford, W. (1952b). "British Congress of Obstetrics and Gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 680.

Gaisford, W. (1953). "Care of the newborn baby". *Paediatrics for the Practitioner. Vol1*. W. Gaisford and R. Lightwood. London, Butterworth & Co. (Publishers), Ltd. **1:** 53-85.

Goddard, R. (1955). "The role of an infant resuscitation team in investigative studies of respiratory onset at birth." *Current Researches in Anaesthesia and Analgesia* **34**(1): 1-25.

Goddard, R. and V. Bennett (1955). "Newer concepts of infant resuscitation and positive-pressure therapy in pediatrics." *AMA: American Journal of Diseases of Children* **89**(1): 70-97.

Greenhill, J. (1955). *Principles and Practice of Obstetrics*. Philadelphia & London, WB Saunders.

Greenwood, M. (1949). "Annual report of M.O.H Essex." *Medical Officer* **81**: 115.

Grundy, F. and E. Lewis-Faning, (Eds.) (1957). *Morbidity and Mortality in the First Year of Life*. Cardiff, The Eugenics Society.

Gupta, J. and J. Tizard (1967). "The sequence of events in neonatal apnoea." *Lancet*: 55-59.

Halperin, M. (1957). "Queries and minor notes: Heart massage in a newborn infant." *JAMA*: 1996.

Hemingway, A. (1944). "An Experimental Study of Different Methods of Artificial Respiration." *BMJ*: p4355-4358.

Hemingway, A. and E. Neil (1944). "An experimental study of different methods of artificial respiration." *BMJ*: 833-836.

Henderson, Y. (1928). "The prevention and treatment of asphyxia in the new-born." *JAMA* **90**(8): 383-386.

Henderson, Y. (1938). *Adventures in Respiration. Modes of Asphyxiation and Methods of Resuscitation*. London, Bailliere, Tindall & Cox.

Henderson, Y., H. Haggard, and Coburn, R.C. (1920). "The therapeutic use of carbon dioxide after anesthesia and operation." *JAMA* **74**(12): 783-786.

Hey, E. and J. Kelly (1968). "Gaseous exchange during endotracheal ventilation for asphyxia at birth." *Journal of Obstetrics and Gynaecology of the British Commonwealth* **75**: 414.

Higgins, L. (1963). "Correspondence: Resuscitation of the newborn." *Lancet* **1**: 999.

Holinger, P. (1955). "Role of the laryngologist in resuscitation of the newborn infant." *JAMA* **159**(14): 1338-1340.

Holmes, J. and J. Payne (1955). "Asphyxia pallida responding to endotracheal insufflation after 140 minutes." *BMJ*: 1071.

Howard, B. (1877a). “The more usual methods of artificial respiration, with demonstration of the “direct method” of the author.” *Lancet* **1**: 194-6.

Howard, B. (1878b). “The direct method of artificial respiration for the treatment of apnoea from drowning, anaesthetics, still-birth, etc.” *Lance* **1***t*: 748-52.

Howard, B. (1878c). “Two exceptional cases of asphyxia neonatorum; their resuscitation by the direct method of artificial respiration.” *Lancet* **1**: 883.

Hughes, J. (1952). *Pediatrics in General Practice*. New York, Toronto & London, McGraw-Hill Book Company, Inc.

Hull, D. (1969). "Lung expansion and ventilation during resuscitation of asphyxiated newborn infants." *Journal of Pediatrics* **75**: 47-55

Hutchison, J.H., Kerr, M.M., Inall, J.A. and Shanks, R.A. (1966). "Controlled trials of hyperbaric oxygen and tracheal intubation in asphyxia neonatorum." *Lancet* **1**: 935-939.

Hutchison, J.H., Kerr, M.M., Williams, K.G. and Hopkinson, W.I. (1963). "Hyperbaric oxygen in resuscitation of the newborn." *Lancet* **1**: 1334-1335.

Hutchison, J. H. (1967). *Practical Paediatric Problems, 2nd Edition*. London, Lloyd-Luke Ltd.

Hutchison, J. H. (1972). *Practical Paediatric Problems, 3rd Edition.* London, Lloyd-Luke Ltd.

Hutchison, J. H. (1975). *Practical Paediatric Problems, 4th Edition.* London, Lloyd-Luke Ltd.

Hutchison, J. H. (1980). *Practical Paediatric Problems, 5th Edition.* London, Lloyd-Luke Ltd.

Hutchison, J.H., Kerr, M.M., Inall, J.A. and Shanks, R.A. (1966). "Treatment of asphyxia neonatorum." *Lancet* **2**: 169.

Hutchison, J.H., Kerr, M.M., Williams, K.G. and Hopkinson, W.I. (1964a). "Hyperbaric oxygen in the resuscitation of the newborn." *Lancet* **1**: 225.

Hutchison, J.H., Kerr, M.M., Williams, K.G. and Hopkinson, W.I. (1964b). "Hyperbaric oxygen in resuscitation of the newborn." *Lancet* **2**: 691-692.

Hutchison JH, K. M., McPhail FM, Douglas TA, Smith G, Norman JN & Bates EH (1962). "Studies in the treatment of the pulmonary syndrome of the newborn." *Lancet* **2**: 465-469.

Hutchison, J. H. and E. M. McGirr (1954). "Hypothyroidism as an inborn error of metabolism." *Journal of Clinical Endocrinology & Metabolism* **14**: 869-886.

Jackson, J. (1953a). "Correspondence: Asphyxia in the newborn." *Lancet* **2**: 834.

Jackson, J. (1953b). "Correspondence: Asphyxia in the newborn." *Lancet* **2**: 1046.

James, L. and K. Adamson (1964). "Medical progress: Respiratory physiology of the fetus and newborn infant." *NEJM* **271**(26): 1352-1360.

James, L. S., Apgar, V., Burnard, E.D. and Moya, F. (1963). "Intragastric oxygen and resuscitation of the newborn." *Acta Paediatrica* **52**: 245-251.

James, L. S., V. Apgar, Moya, F., Kvisselgaard, N., Burnard, E.D., Brady, J., Tuchman, W., Crawford, J.S. and Holiday, D.A. (1963). "Intragastric oxygen: Experimental observations in newborn puppies." *Acta Paediatrica* **52**: 241-244.

James, L. S., Moya, F., Burnard, E.D. and Apgar, V. (1959). "Letter to the editor: intragastric administration of oxygen." *Lancet* **1**: 737.

James, L. S. (1967). "Scientific basis for current perinatal care." *Archives of Disease in Childhood* **42**: 457-466.

Johnson, B. (1959). "An infant resuscitation trolley." *BJOG: An International Journal of Obstetrics and Gynaecology* **66**(3): 492.

Johnson, K. and S. Babson (1967). "Resuscitation of the apneic premature infant." *Pediatrics* **40**(1): 99-100.

Killick, E. and F. Eve (1933). "Physiological investigation of the rocking method of artificial respiration." *Lancet* **1**: 740-742.

Kouwenhoven, W., Jude, J. and Knickerbocker, G.G. (1960). "Closed-chest cardiac massage." *JAMA* **173**(10): 1064-1067.

Kreiselman, J. (1943). "A new resuscitation apparatus." *Anesthesiology* **4**(6): 608-611.

Kreiselman, J. (1945a). "The treatment of asphyxia." *Southern Medical Journal* **38**: 598-604.

Kreiselman, J. (1945b). "The treatment of asphyxia." *Journal of the Connecticut Medical Society* **9**: 94-99.

Kreiselman, J. (1945c). "The treatment of asphyxia." *Anesthesiology* **6**(6): 654-655.

Kreiselman, J. (1946). "The treatment of asphyxia." *Obstetrical and Gynecological Survey* **1**(2): 203-204.

Koplik, H. (1903). *The Diseases of Infancy and Childhood. Designed for the use of students and practitioners of medicine*. London, Henry Kimpton.

Leak, W. (1941). "Correspondence: Treatment of asphyxia neonatorum." *Lancet* **1**: 433.

Lennon, N. K. (1952). "British Congress of Obstetrics and Gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 679-680.

Lord, J.M., Powell, B.W. and Roberts, H. (1953). "Treatment of asphyxia neonatorum." *Lancet* **2**: 1001-1004.

Lowe, C. and T. McKeown (1954). "Incidence of infectious diseases in the first three years of life, related to social circumstances." *British Journal of Preventative and Social Medicine* **8**: 24.

MacGregor, A. (1946). "The pathology of still-birth and neonatal death. A review of 1053 cases." *British Medical Bulletin* **4**: 174-178.

Macintosh, R. and W. Mushin (1946). "Pulmonary exchange during artificial respiration." *BMJ*: 908-909.

Mann, J. (1953). "Method and machine for resuscitation of the newborn." *JAMA* **152**(14): 1333-1335.

Mason, M.F., Kennedy, J. and Barcroft, J. (1938). "Direct determination of foetal oxygen consumption." *Journal of Physiology* **93**: 21-22.

Mathieu, A. and A. Holman (1929). "Resuscitation of the asphyxiated new-born." *JAMA* **92**(23): 1917-1918.

McCance, R. (1961). "Foetal and neonatal physiology: Introduction." *British Medical Bulletin* **17**(2): 79-80.

McGirr, E. M. and J. H. Hutchison (1953). "Radioactive-iodine studies in non-endemic goitrous cretinism." *Lancet* **262**: 403.

McGirr, E. M. and J. H. Hutchison (1955). "Dysgenesis of the thyroid gland as a cause of cretinism and juvenile myxedema." *Journal of Clinical Endocrinology & Metabolism* **15**: 668-679.

McGrath, J. and K. Kuder (1936). "Resuscitation of the new-born." *JAMA* **106**(11): 885-890.

Millen, R. and J. Davies (1946). "See-saw resuscitator for the treatment of asphyxia in the newborn." *American Journal of Obstetrics and Gynaecology* **52**: 508-509.

Millen, R., A. Rowsom, et al. (1955). "Prevention of neonatal asphyxia with the use of a rocking resuscitator." *American Journal of Obstetrics and Gynaecology* **70**: 1087-1091.

Miller, H. and N. Smull (1955). "Further studies on the effects of hypoxia on the respiration of newborn infants." *Pediatrics* **16**: 93-103.

Moncrieff, A. (1935a). "Respiratory failure including so-called asphyxia neonatorum." *Lancet* **1**: 531-536.

Moncrieff, A. (1935b). "Respiratory failure including so-called asphyxia neonatorum." *Lancet* **1**: 595-600.

Moncrieff, A. (1935c). "Respiratory failure including so-called asphyxia neonatorum." *Lancet* **1**: 664-669.

Morris, W. I. C. (1952). "British Congress of Obstetrics and Gynaecology: The place of the paediatrician in a maternity unit." *BJOG: An International Journal of*

Obstetrics and Gynaecology **59**(5): 677-678.

Moss, P. (1963). "Hyperbaric oxygen in the resuscitation of the newborn." *Lancet* **2**: 1124.

Moya, F. and E. D. Burnard (1961). "Current comment: Closed chest cardiac massage in the newborn." *Anesthesiology* **22**(4): 644-645.

Moya, F., James, L.S., Burnard, E.D. and Hanks, E.C. (1962). "Cardiac massage in the newborn infant through intact chest." *American Journal of Obstetrics and Gynecology* **84**: 798.

Neligan, G. (1963). "Correspondence: Resuscitation of the newborn." *Lancet* **1**: 1049.

Neligan, G. (1968). "Correspondence: Resuscitation of the newborn." *Lancet* **2**: 347.

Nelson, P. K. (1960). "Letter to the editor: Intragastric oxygen." *Lancet* **2**: 317-318.

O'Brien, D. and H. Roberts (1952). "Endotracheal insufflation with oxygen in the treatment of asphyxia neonatorum." *BMJ*: 963-964.

Ostry, E. (1951). "Instrument for gastro-intestinal administration of oxygen in asphyxia of newborn." *Journal of Obstetrics and Gynaecology of the British Empire* **58**(6): 1034.

Parsons, L. and Barling, S. (1933). *Diseases of Infancy and Childhood*. London, Oxford University Press & Humphrey Milford.

Parsons, L., and Barling, S. (1954). *Diseases of Infancy and Childhood, 2nd Edition*. London, New York & Toronto, Oxford University Press.

Paterson, D. and J. McCready (1956). *Pediatrics*. Philadelphia & Montreal, JB Lippincott Company.

Patterson, J. (1968). "Correspondence: Resuscitation of the newborn." *Lancet* **2**: 347-348.

Pavey, C. (1946). "Modification of the Ericson and Johnson Resuscitator." *American Journal of Obstetrics and Gynaecology* **52**: 867-868.

Pfaundler, M. and Schlossman, A. (1908). *The Diseases of Children. A work for the practicing clinician.* Philadelphia & London, JB Lippincott.

Phillips, M. (1938). "Correspondence: Asphyxia neonatorum." *Lancet* **2**: 916.

Politi, V. (1957). "Resuscitation of the newborn." *Canadian Anaesthetist's Society Journal* **4**(2): 118-125.

Potter, E. (1955). "State of the lungs at birth." *JAMA* **159**(14): 1341.

Rees, J. (1963). "Management of neonatal asphyxia". *The Obstetrician, Anaesthetist and Obstetrician in the Management of Obstetric Problems.*

Transactions of the South-Western Obstetrical and Gynaecological Society's Autumn Meeting Held at Portsmouth 7-10 November 1961. T. Barnett and J. Foley. Oxford, Pergamon**:** 125-132.

Reichelderfer, T. and H. Nitowsky (1956). "A controlled trial of the use of the Bloxsom Air Lock." *Pediatrics* **18**: 918-927.

Roberts, H. (1949). "An anaesthetists contribution to the resuscitation of the newborn." *BJOG: An International Journal of Obstetrics and Gynaecology* **56**(6): 961-970.

Rodger, J.C., Kerr, M.M., Richards, I.D. and Hutchison, J.H. (1968). "Measurements of oxygen tension in subcutaneous tissues of newborn infants under normobaric and hyperbaric conditions." *Lancet* **2**: 232-236.

Russ, J. and R. Strong (1941). "Resuscitation of the asphyxiated newborn infant." *American Journal of Diseases of Children* **61**(1): 1-12.

Sarnoff, S. (1951). "Correspondence: Electrophrenic respiration in asphyxia beonatorum." *BMJ*: p1515.

Schaffer, A. (1960). *Diseases of the Newborn*. Philadelphia & London, WB Saunders Co.

Schmidt, O., M. McLandress, et al. (1956). "An Evaluation of Infant Resuscitation." *Canadian Medical Journal* **75**: 503-506.

Scott, J. (1968). "Correspondence: Resuscitation of the newborn." *Lancet* **2**: 167.

Seward, E. (1957). "New Inventions. Laryngoscope for resuscitation of the newborn." *Lancet* **2**: 1041.

Sheldon, W. (1936). *Diseases of Infancy and Childhood*. London, J & A Churchill Ltd.

Sheldon, W. (1940). *Diseases of Infancy and Childhood,* 4th edition. London, J & A Churchill Ltd.

Sheldon, W. (1946). *Diseases of Infancy and Childhood,* 5th edition. London, J & A Churchill Ltd.

Sheldon, W. (1951). *Diseases of Infancy and Childhood 6th edition*. London, J &A Churchill Ltd.

Sheldon, W. (1955). *Diseases of Infancy and Childhood, 7th edition*. London, J & A Churchill Ltd.

Silverman, W. A. (1966). "Treatment of asphyxia neonatorum." *Lancet* **2**: 168-169.

Smith, A. A. (1952). "British Congress of Obstetrics and Gynaecology: The Place of the Paediatrician in a Maternity Unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 676-677.

Smith, B. (1965). "Resuscitation of the depressed newborn." *Anesthesiology* **26**:

549-561.

Smith, C. (1945). *The Physiology of the Newborn Infant*. Springfield, Illinois, Charles C. Thomas.

Smith, C. and C. Cook (1955). "American Academy of Pediatrics, Inc. Proceedings and Reports: Special Problems of the Newborn." *Pediatrics* **15**(3): 348-352.

Snyder, F. and M. Rosenfeld (1937). "Direct observation of intrauterine respiratory movements of the fetus and the role of carbon dioxide and oxygen in their regulation." *American Journal of Physiology* **119**: 153-166.

Spence, J., W. Walton, et al. (1954). *A Thousand Families in Newcastle-Upon-Tyne.* Oxford, Oxford University Press.

Stabler, F. (1952). "British Congress of Obstetrics and Gynaecology: The Place of the Paediatrician in a Maternity Unit." *BJOG: An International Journal of Obstetrics and Gynaecology* **59**(5): 666-670.

Steel, G. (1954). "New inventions: A portable infant resuscitator." *Anaesthesia* **9**(4): 309.

Steen, T. (1963). "Correspondence: Resuscitation of the Newborn." *Lancet*: 999.

Storah, P. (1951). "Apparatus for resuscitation of the newborn." *Irish Journal of Medical Science* **6**(306): 289-292.

Sutherland, J. and H. Epple (1961). "Cardiac massage of stillborn infants." *Obstetrics and Gynecology* **18**(2): 182-186.

Tarachand, N. (1894). “A case of asphyxia neonatorum.” *Lancet* **2**: 1277.

Thaler, M. and G. Stobie (1963). "An improved technic of external cardiac compression in infants and young children." *NEJM* **269**(12): 606-610.

Thomson, J. (1952). "The incidence of foetal and infant mortality in 13,085 births in a maternity hospital. An inquiry into the influence of non-obstetric factors on the difference between the booked and the non-booked foetal and infant mortality." *Journal of Obstetrics and Gynaecology* **59**(4): 483-490.

Toaff, R. and B. Eckerling (1954). "Gastrointestinal administration of oxygen in asphyxia of the newborn." *Obstetrics and Gynecology* **3**(4): 366-370.

Tovell, R. and D. Little (1955). "Resuscitation of the newborn infant." *JAMA* **159**(14): 1337-1338.

Tunstall, M. (1964). "Neonatal resuscitation." *British Journal of Anaesthesia* **36**: 591-599.

Waller, H. and D. Morris (1953). "Resuscitation of the newborn with intragastric oxygen (Akerren's method)." *Lancet*: 951-953.

Watson-Williams, P. (1935). "Asphyxia neonatorum: Its treatment by tracheal intubation." *Lancet*: 964.

Wegman, M. (1950). "Trend in infant mortality rates." *Pediatrics* **6**: 673-675.

Williams, J. (1906). *Obstetrics: A textbook for the use of students and practitioners*. New York, D Appleton and Company.

Wilson, J. (1954). "Factors involved in the production of alveolar rupture with mechanical aids to respiration." *Pediatrics* **13**: 146-149.

Wilson, R.A., Torrey, M.A. and Johnson, K.S. (1937). "The initiation of respiration in asphyxia neonatorum." *Surgery, Gynecology and Obstetrics* **65**(5): 601-622.

Windle, W. and J. Barcroft (1938). "Some factors governing the initiation of respiration in the chick." *American Journal of Physiology* **121**: 684-691.

Woody, N. and H. Woody (1968). "Direct digital intratracheal intubation for neonatal resuscitation." *The Journal of Pediatrics* **73**(6): 901-905.

Wulfsohn, N. (1955). "A simple apparatus for resuscitation of the newborn." *BJOG: An International Journal of Obstetrics and Gynaecology* **62**(4): 612-613.

Ylppö, A. (1935). "Über Die Behandlun Der Atemstörungen Bei Frühgeburten Durch Direkte Zufuhr Von Sauerstoff in Den Magen." *Acta Paediatrica* **17**(Supp 1): 122-130.

Secondary Literature

[Anon] (1989). "Hutchison, James Holmes." *Munk's Roll* **8**: 239-240.

[Anon] (1995). "L. Stanley James, M.D." *P&S Journal* **15**(1): http://www.cumc.columbia.edu/news/journal/journal o/archives/jour_v15n11_0047.html.

[Anon] (2005). “Committee report: American pediatrics: Milestones at the millennium”. *Pediatrics* **107**(6): 1482-1491.

Apple, R.D. (1987). *Mothers and Medicine: A social history of infant feeding, 1890-1950.* Madison, University of Wisconsin Press.

Ashwell, M. (1993). *Mc Cance and Widdowson: A scientific partnership of 60 years, 1933-1993.* London, British Nutrition Foundation.

Austoker, J. and Bryder, L. (1989). *Historical perspectives on the role of the M.R.C.: Essays in the history of the Medical Research Council of the United Kingdom and its predecessor, the Medical Research Committee, 1919-1953*. Oxford & New York, OUP.

Avery, M. (1992). "A 50-year overview of perinatal medicine." *Early Human Development* **29**: 45-50.

Avery, M. (1998). "Neonatology (pioneers and modern ideas)." *Pediatrics* **102**(Supp 1): 270-271.

Baker, J.P. (1996). *The Machine in the Nursery: Incubator Technology and the Origins of Newborn Intensive Care*. Baltimore, Johns Hopkins University Press.

Ballowitz, L. (1981). “Arvo Ylppö”. In *Historical Review and Recent Advances in Neonatal and Perinatal Medicine, vol 1.* Illinois, Mead Johnson Nutrition Division: ix-xi.

Barnes, B. (1974). *Scientific Knowledge and Sociological Theory*. London & Boston, Routledge & Kegan Paul.

Baskett, T. (2000). "The resuscitation greats: Virginia apgar and the newborn apgar score." *Resuscitation* **47**: 215-217.

Baskett, T. (2005). "Eve's rocking method of artificial respiration." *Resuscitation* **65**: 245-247.

Berridge, V. (2000). "Health, medicine and social policy: The rise of the longer twentieth century?" *Journal of Contemporary History* **35**: 667-677.

Berridge, V. (1999). *Health and Society in Britain since 1939*. Cambridge , Cambridge University Press.

Bliss, M. (182). *The Discovery of Insulin*. Chicago, University of Chicago Press.

Bloor, D. (1976). *Knowledge and social imagery*. London, Henley & Boston, Routledge & Kegan Paul.

Blume, S. (2003). "Medicine, technology and industry". in *Companion to twentieth century medicine*. R. Cooter and J. Pickstone (Ed.). London, Routledge**:** 171-185.

Bonner, T.N. (1995). *Becoming a physician: medical education in Britain, France, Germany and the United States.* New York, OUP.

Booth, C. (1985). "Medical science and technology at the Royal Postgraduate Medical School: The first 50 years." *BMJ* **291**: 1771-1779.

Booth, C. (1987). “Clinical research and the MRC”. In *Doctors in Science and Society. Essays of a clinical scientist*. Cambridge, Cambridge University Press: 238-262.

Booth, C. (2003). "From art to science: The story of clinical research". in *A physician reflects: Herman Boerhaave & other essays*(Ed.). London, Wellcome Trust.

Booth, J. (2000). "Tracheostomy and tracheal intubation in military history." *Journal of the Royal Society of Medicine* **93**: 380-383.

Bourke, J. (2003). "Wartime". in *Companion to medicine in the twentieth century*. R. Cooter and J. Pickstone (Ed.). London & New York, Routledge**:** 589-600.

Brandt, A.M. and Gardner, M. (2003). “The Golden Age of Medicine?” in *Companion to Twentieth Century Medicine.* Cooter, R. and Pickstone, J. (Eds.). London, Routledge: 21-37.

Burnham, J. C. (2008). "Accident proneness (unfallneigung): A classic case of simultaneous discovery/construction in psychology." *Science in Context* **21**: 99-118.

Burrows, E.H. (1987). *Pioneers and the Early Years: A History of British Radiology*. Alderney, C.I. Colophon.

Bynum, W.F., Hardy, A., Jacyna, S., Lawrence, C. and Tansey, E.M. (Eds.) (2006) *The Western Medical Tradition, 1800 to 2000.* New York, Cambridge University Press.

Calnan, J. (1985). *The Hammersmith : the first 50 years of the Royal Postgraduate Medical School at Hammersmith Hospital*. Lancaster, M.T.P.

Christie, D. and E. Tansey (Eds.) (1999). *Origins of neonatal intensive care in the UK*. London, Wellcome Trust.

Cone, T. (1985). *History of the care and feeding of the premature infant*. Boston/Toronto, Little, Brown and Company.

Constant II, E. W. (1978). "On the diversity and co-evolution of technological multiples: Steam turbines and pelton water wheels." *Social Studies of Science* **8**(2): 183-210.

Cooper, E. A. (1995). "On the efficiency of intragastric oxygen." *Anaesthesia* **50**: 535.

Cooper, R. (2004). "Laryngoscopy - its past and future." *Canadian Journal of Anesthesia* **51**(6): R1-R5.

Cooter, R. (1992). "The politics of a spatial innovation: fracture clinics in inter-war Britain". In *Medical Innovations in Historical Perspective*. Pickstone, J.V. (Ed.). London, Macmillan.

Cooter, R. (1993). *Surgery and Society in Peace and War*. London, Macmillan.

Cooter, R. (2003). "The ethical body". in *Companion to Medicine in the Twentieth Century*. R. Cooter and J. Pickstone (Ed.). London, Routledge**:** 451-468.

Cooter, R., Harrison, M. and Sturdy, S. (Eds.) (1998). *War, medicine and modernity*. Stroud, Sutton.

Cooter, R., Harrison, M. and Sturdy, S. (Eds.) (1999). *Medicine and Modern Warfare*. Amsterdam & Atlanta, Rodopi.

Crane, D. (1972). *Invisible colleges. Diffusion of knowledge in scientific communities*. Chicago & London, The University of Chicago Press.

Cunningham, A. and Williams, P. (1992). *The Laboratory Revolution in Medicine*. Cambridge & New York, Cambridge University Press.

Davis, J.A. (1994). "Kenneth William Cross". *Munk's Roll* **9:** 107-109.

Davis, J.A. (1996). “Tizard, Sir (John) Peter (Mills)”. *Munk's Roll* **9:** 518-520.

Davis, J.A. (2000). “Leonard Birnie Stran”. *Munk's Roll* **10:** 472-474.

Dunn, P. (2002). “Sir Leonard Parsons of Birmingham (1879-1950) and antenatal paediatrics”. *Archives of Disease in Childhood: Fetal & Neonatal Edition* **86** (1): F65-7.

Dunn, P. (2001). “Perinatal lessons from the past. Julius Hess, MD, (1876-1955) and the premature infant”. *Archives of Disease in Childhood: Fetal & Neonatal Edition* **85** (2): F141-4.

Dunn, P. (2001). “Wilhelm Conrad Röentgen (1845-1923), the discovery of x rays and perinatal diagnosis”. *Archives of Disease in Childhood: Fetal & Neonatal Edition* **84** (2): F138-9.

Dunn, P. (2001). “Julius Hess, M.D. (1876-1955) and the premature infant”. *Archives of Disease in Childhood: Fetal & Neonatal Edition* **85**: 142.

Dwork, D. (1987). *War is good for babies and other young children: a history of the infant and child welfare movements in England, 1898-1918*. London, Tavistock.

Faden, R. and T. Beauchamp (1986). *A history and theory of informed consent*. New York, OUP.

Frickel, S. and N. Gross (2005). "A general theory of scientific/intellectual movements." *American Sociological Review* **70**(Apr): 204-232.

Gieryn, T. F. (1983). "Boundary-work and the demarcation of science from non-science: Strains and interests in professional ideologies of scientists." *American Sociological Review* **48**(Dec): 781-795.

Gieryn, T. F. (1999). *Cultural boundaries of science: Credibility on the line*. Chicago, Chicago University Press.

Golden, J. (1998). *A Social History of Wet Nursing in America: From Breast to Bottle.* New York, Cambridge University Press.

Goldsmith, J. and E. Karotkin (1996). "Introduction to assisted ventilation". in *Assisted ventilation of the neonate*. J. Goldsmith and E. Karotkin (Ed.). Philadelphia, WB Saunders Co.**:** 1-19.

Goldstein, P. (1980). "Birth asphyxia". in *Historical review and recent advances in neonatal and perinatal medicine*. G. Smith and D. Vidyasagar (Ed.). Illinois, Mead Johnson Nutritional Division. **vol.1:** 177-184.

Harden, V.A. (1986). *Inventing the N.I.H.: federal biomedical research policy, 1887-1937.* Balitmore, Johns Hopkins University Press.

Hardy, A. and E.M. Tansey (2006). “Medical enterprise and the global response, 1945-2000”. In *The Western Medical Tradition 1800 to 2000*. Bynum, W.F., Hardy, A., Jacyna, S., Lawrence, C. and Tansey, E.M. (Eds.) New york, Cambridge University Press: 405-534.

Hughes, J. and T. Söderqvist (1999). "Why is it so difficult to write the history of contemporary science?" *Endeavour* **23**(1): 1-2.

Hull, A. (2001). "Hector's house: Sir Hector Hetherington and the academicization of Glasgow hospital medicine before the NHS." *Medical History* **45**: 207-242.

Hull, A. (2007). "Teamwork, clinical research, and the development of scientific medicines in interwar Britain: The "Glasgow school" revisited." *Bulletin of the History of Medicine* **81**: 569-596.

Hyman, A. (1985). "History of resuscitation of newborn infants". in *Anaesthesia - essays on its history*. J. Ruprecht, M. J. Van Lieburg*et al* (Ed.). Berlin & Heidelberg, Springer - Verlag**:** 141-143.

Jeffrey, K. (1995). "Pacing the heart: Growth and redefinition of a medical technology, 1952-1975." *Technology and Culture* **36**: 583-624.

Jenner, M. S. R. and B. O. Taithe (2003). "The historiographical body". in *Companion to Medicine in the Twentieth Century*. R. Cooter and J. Pickstone (Ed.). London, Routledge.

Johnson, L. (1980). “Shared remembrances of Richard L Day”. In *Historical review and recent advances in neonatal and perinatal medicine*. Smith, G.F. and Vidyasagar, D. (Eds.). Illinois, Mead Johnson Nutrition Division: xvi-xviii.

Jordanova, L. (2004). “The Social Construction of Medical Knowledge”. In *Locating Medical History: The Stories and Their Meanings*. Huisman, F & Harley Warner, J (Eds.). Baltimore and London, The Johns Hopkins University Press: 338-363

Kendig, J. W., P. G. Maples, et al. (2001). "The bloxsom air lock: A historical perspective." *Pediatrics* **108**(6): e116.

Knight, N. (1986). “The new light: X-rays and medical futurism”. In *Imagining Tomorrow*. Corn, J.J (Ed.). Cambridge, Mass., MIT Press: 10-34.

Lawrence, C. (1985). "Incommunicable knowledge: Science, technology and the clinical art in Britain 1850-1914." *Journal of Contemporary History* **20**(4): 503-520.

Lawrence, C. (1985). “Moderns and Ancients: The "new cardiology" in Britain 1880-1930”, *Medical History* **Supplement 5**:1-33.

Lawrence, C. (1999). “A Tale of Two Sciences: Bedside and bench in twentieth-century Britain”. *Medical History* 43: 421-449

Lawrence, C. (2005). *Rockefeller Money, the Laboratory and Medicine in Edinburgh 1919-1930. New science in an old country*. Rochester, University of Rochester Press.

Lawrence, C. and G. Weisz, (Eds.) (1998). *Greater than the Parts, Holism in Biomedicine, 1920-1950*. New York, OUP.

Lawrence, G., (Ed.) (1994). *Technologies of Modern Medicine*. London, Science Museum.

Lievrouw, L. A. (1989). "The invisible college reconsidered. Bibliometrics and the development of scientific communication theory." *Communication Research* **16**(5): 615-628.

Liggins, G. (1998). "Geoffrey Sharman Dawes C.B.E." *Biographical Memoirs of Fellows of the Royal Society* **44**: 110-125.

Loudon, I. (1992). *Death in Childbirth. An International Study of Maternal Care and Maternal Mortality, 1800 - 1950.* Oxford, Clarendon Press.

Lussky, R. (1999) "A century of neonatal medicine." *Minnesota Medicine* **82**, http://www.mnmed.org/publications/MnMed1999/December/Lussky.cfm?PF=1.

MacFarquhar Desmond, M. (1998). *Newborn Medicine and Society. European background and American practice (1750-1975).* Austin, Eakin Press.

Marks, S. (1992). “Mothers, babies and hospitals: 'The London' and the provision of maternity care in East London, 1870-1939. in *Women and children first. International maternal and infant welfare, 1870-1945*. Fildes, V.Marks, S. and Marland, H. (Eds.). London & New York, Routledge: 48-73.

Marland, H. (2003). "Childbirth and maternity". in *Companion to Medicine in the Twentieth Century*. J. Pickstone and R. Cooter (Ed.). London & New York, Routledge**:** p559-574.

McGehee, H.A. (1981). *Science at the Bedside. Clinical Research in American Medicine 1905-1945*.Baltimore & London, Johns Hopkins University Press.

Meadow, R. (2004): “Tizard, Sir (John) Peter Mills (1916-1993)”. *Oxford Dictionary of National Biography*, Oxford University Press.
http://www.oxforddnb.com/view/article/53373

Meckel, R. (1990). *Save the babies. American public health reform and the prevention of infant mortality, 1850-1929*. Baltimore & London, Johns Hopkins University Press.

Merton, R. (1973). "Multiple discoveries as a strategic research site". in *The Sociology of Science* (Ed.). Chicago, University of Chicago Press**:** 371-383.

Nelson, N. (1980). "An appreciation of Clement A Smith". in *Historical review and recent advances in neonatal and perinatal medicine*. G. Smith and D. Vidyasagar (Ed.). Illinois, Mead Johnson Nutrition Division. **1:** xii-xiii.

Nelson, N. (1980). "Perinatal medicine". in *Historical review and recent advances in neonatal and perinatal medicine.* G. Smith and D. Vidyasagar (Ed.). Illinois, Mead Johnson Nutritional Division. **vol. 1:** 3-8.

Nelson, N. (2000). "A decimillenium in neonatology." *Journal of Pediatrics* **137**: 731-735.

Nicolson, M. and Lowis, G. (2002). “The early history of the Multiple Sclerosis Society of Great Britain and Northern Ireland: A study of lay/practitioner interaction in the context of a medical charity”. *Medical History* **46**: 141-174.

Nicolson, M., J. Fleming, et al. (2005). "Hyaline membrane and neonatal radiology - Ian Donald's first venture into imaging research." *Scottish Medical Journal* **50**: 35-37.

Normon, A.P. (2004). “Moncrieff, Sir Alan Aird (1901–1971)”. *Oxford Dictionary of National Biography*, Oxford University Press. http://www.oxforddnb.com/view/article/37778?docPos=2

Nye, R. (1997). "Medicine and science as masculine ‘fields of honor'." *Osiris* **12**: 60-79.

Nye, R. (2003). "The evolution of the concept of medicalization in the late twentieth century." *Journal of the History of the Behavioural Sciences* **39**: 115-129.

O'Donnell, C., A. Gibson, et al. (2006). "Pinching, electrocution, raven's beaks, and positive pressure ventilation: A brief history of neonatal resuscitation." *Archives of Disease in Childhood. Fetal and Neonatal Edition* **91**: F369-373.

Oransky, I. (2005). "Obiturary: William Silverman." *Lancet* **1**: 116.

Pickstone, J.V. (1999). *Medical innovation in historical perspective*. Basingstoke & London, Macmillan Press Ltd.

Pickstone, J.V. (2003). “Production, Community and Consumption: The Political Economy of Twentieth-Century Medicine” in *Companion to Medicine in the Twentieth Century*. R. Cooter and J. Pickstone (Ed.). London, Routledge: 1-19.

Philip, A. G. S. (2005). "The evolution of neonatology." *Pediatric Research* **58**(4): 799-815.

Price, D. J. D. (1963). *Little Science, Big Science*. New York, Columbia University Press.

Raju, T. (1999). "History of neonatal resuscitation. Tales of heroism and desperation." *Clinics in Perinatology* **26**(3): 629-640.

Redman, C. (2004). “Dawes, Geoffrey Sharman (1918-1996)”. *Oxford Dictionary of National Biograph*y, Oxford University Press. http://www.oxforddnb.com/view/article/62623

Rendell-Baker, L. and J. Jacobson (1999). "Hyperbaric oxygenation." *International Anaesthesiology Clinics* **37**(1): 137-167.

Reynolds, L. and E. M. Tansey, (Eds.) (2000). *Clinical Research in Britain, 1950–1980*. London, Wellcome Trust.

Reynolds, L. and E. M. Tansey, (Eds.) (2005). *Prenatal Corticosteroids for reducing morbidity and mortality after preterm birth*. London, Wellcome Trust.

Richmond, C. (2007). “Obituary Thomas Oppe”, *The Independent*, 24th November.

Robertson, A. (2003a). "Reflections on errors in neonatology i: The 'hands-off' years, 1920 to 1950." *Journal of Perinatology* **23**: 48-55.

Robertson, A. (2003b). "Reflections on errors in neonatology ii: The 'heroic' years, 1950 to 1970." *Journal of Perinatology* **23**: 154-161.

Robertson, A. (2003c). "Reflections on errors in neonatology iii: The 'experienced' years, 1970 to 2000." *Journal of Perinatology* **23**: 240-249.

Rothman, D. (1991). *Strangers at the bedside*. New York, Basic Books.

Shapin, S. (1995). "Here and Everywhere: Sociology of Scientific Knowledge". *Annual Review of Sociology* **21**: 289-321.

Sheridan, R. (1999). "Hyperbaric oxygen treatment: A brief overview of a controversial topic." *The Journal of Trauma: Injury, Infection, and Critical Care* **47**(2): 426-435.

Silverman, W. (1980). *Retrolental Fibroplasia: A modern parable.* New York & London, Grune and Stratton.

Silverman, W. (1985). *Human Experimentation: A guided step into the unknown*. Oxford, OUP.

Silverman, W. (1989). "Neonatal pediatrics at the century mark." *Perspectives in Biology and Medicine* **32**(2): 159-170.

Silverman, W. (1992). "Overtreatment of neonates? A personal retrospective." *Pediatrics*: 971-976.

Silverman, W. (1994). "Letter to the editor: 'writing history is like trying to nail jelly to the wall'- robin winks." *Acta Paediatrica* **83**: 684.

Speert,H. (2004). "Memorable Medical Mentors: V. Nicholson J. Eastman*". Obstetrical and Gynecological Survey* **59**(6): 399-405.

Sturdy, S. (1992). "From the trenches to the hospitals at home: Physiologists, clinicians and oxygen therapy." in *Medical innovations in Historical Perspective*. J. Pickstone (Ed.). Houndsmill, Basingstoke, Macmillan Press Ltd**:** 104-123.

Sturdy, S. (2007). "Scientific method for medical practitioners: the case method of teaching pathology in early twentieth century Edinburgh" *Bulletin of the History of Medicine* **81**:760-792.

Szmuk, P., Ezri, T., Evron, S., Roth, Y. and Katz, J. (2008). "A brief history of tracheostomy and tracheal intubation, from the bronze age to the space age." *Intensive Care Medicine* **34**: 222-228.

Timmerman, C. T. and J. Anderson, Eds. (2006). *Devices and Designs. Medical Technologies in Historical Perspective*. Basingstoke & New York, Palgrave Macmillan.

Viner, R. (1999). "Using the history of pediatrics." *Health and History* **1**: 161-167.

Wainwright, M. (1990*). Miracle Cure: The story of penicillin and the golden age of antibiotics.* Oxford, U.K. & Cambridge, U.S.A., Blackwell.

Weisz, G. (2006). *Divide and Conquer: A Comparative History of Medical Specialization*. New York, OUP.

West, J.B. (2004). "Barcroft, Sir Joseph (1872–1947)2. Oxford Dictionary of National Biography, Oxford University Press. http://www.oxforddnb.com/view/article/30580?docPos=3

Widdowson, E.M. (1995). "Robert Alexander Mc Cance". *Biographical Memoirs of Fellows of the Royal Society*. **41**: 263-280.

Williams, A. (1997). *Women & Childbirth in the Twentieth Century. A History of the National Birthday Trust Fund 1928-93.* Gloucestershire, Sutton Publishing.

Writer, D. (2004). "Sir Edward Sharpey-Schafer and his simple and efficient method of performing artificial respiration". *Resuscitation* **61** (2):113-116.