FOETAL CEPHALOMETRY BY ULTRASOUND

AND ITS PLACE IN CLINICAL OBSTETRICS

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CONTENTS

INTRODUCTION

This thesis describes work done in Professor Ian Donald's Unit at the Glasgow Royal Maternity Hospital, where the author is Senior Registrar. During the past three years, a method of measuring the biparietal diameter of the foetal head in utero by the reflection of pulsed ultrasound has been developed and has had extensive practical use.

An industrial ultrasonic flaw detector is used to direct a beam of pulsed ultrasound through the maternal abdomen and the same transducer is used to detect echoes from reflecting objects in the path of the beam. Characteristic echoes from each side of the foetal head can be identified and have simultaneous maximum amplitude when the beam of ultrasound is directed along the biparietal diameter. The time between the arrival of echoes from the near and far sides of the foetal head is measured and, as the result of experimental work, the biparietal diameter in centimetres can be calculated.

On the basis of the work done it is believed that the speed of ultrasound in the living brain of the newborn child is 1524 metres per second, a figure which is in good agreement with other published work. After birth, alterations in the biparietal diameter have been observed in the first day of life, when a decrease is not uncommon: thereafter, the diameter does not change appreciably during the first week of life.

The method compares favourably with cephalometry by x-rays and can be used in a number of situations where x-ray cephalometry is impossible. The examination is simple and safe and the result is immediately available to the clinician. The method is used to define presentation in doubtful cases, to assess foetal size, and to observe foetal growth by making repeated measurements after the 28th week of pregnancy. Observations have indicated that the average rate of growth of the biparietal diameter in the last 10 weeks of pregnancy is 1.76 millimetres a week.

The technique used for foetal cephalometry has also been used to demonstrate intracranial lesions in newborn infants, as described in the appendix.

THE PLACE OF FOETAL CEPHALOMETRY IN OBSTETRICS

The cardinal importance of knowledge of the size and shape of the foetal head in order to understand the mechanism of labour was recognised by SMELLIE (1752), who also pointed out that it is the biparietal diameter which passes through the narrowest part of the brim of the pelvis. DENMAN (1795), in advocating the induction of premature labour in cases of contracted pelvis, regretted that it was impossible to make accurate measurements on which to base the indications for the operation.

"It would be highly satisfactory," he wrote, "if I were able to state with precision the exact dimensions of the cavity of the pelvis of the person on whom it might be needful to perform this operation, and on whom it might be performed with success. But, as all the instruments and methods contrived for measuring the pelvis in the living woman too imperfectly answer this purpose, to enable us by them to form an unerring guide to practice: and as the head of a child before it is born can never be accurately measured, of course the exact relation between them must be unknown, and the determination must be therefore left to opinion".

The art of pelvimetry developed following the classic work of MICHAELIS (1851), but it was not until 1899 that PERRET introduced a method of cephalometry by means of callipers placed on the maternal abdomen. GREENHILL (1955)

states that surprisingly accurate results are obtained by this method, but MUNRO KERR and MOIR (1956) dismiss it as being of no practical importance. The method has, together with external pelvimetry, sunk into justified oblivion following the introduction of x-rays.

Numerous methods of x-ray cephalometry have been developed but no attempt will be made here to describe the technical details.

Cephalometry has been used for two main reasons -

1. To assess disproportion.

2. To assess the growth and maturity of the foetus.

SCAMMON and CALKINS (1922, 1929) were among the earliest workers to use cephalometry as an index of foetal growth and maturity. They stated that the biparietal diameter increased by 2.5 mm. a week.

REECE (1935) also used the biparietal diameter to assess maturity and found a similar rate of growth.

INCE (1939), in a large series of measurements, correlated the biparietal diameter with the birth weight of the child and evolved the following formula.

$$W = (4.62 \times B) - 9.79$$

Where W = weight in pounds, B = Biparietal diameter in inches

(See Table I)

JOSEPHS (1949) measured the biparietal diameter radiologically in 189 cases in the last four weeks of pregnancy and again by calliper three days after birth when

TABLE I(FROM HASTINGS INCE)
RELATION OF BODY WEIGHT TO BIPARIETAL DIAMETER OF HEAD

Biparietal Diameter in inches	Observed						Estimated Weight		Number of Cases
	Minimal Weight		Average Weight		Maximal Weight				
	lbs	ozs	lbs	ozs	lbs	ozs	lbs	ozs	
2.75	3	0	3	0	-		2	15	1
2.95	2	10½	2	10½	-		3	13½	1
3.05	2	13	2	13	-		4	4	1
3.20	3	0	4	6¾	5	11½	5	0	6
3.25	7	0	7	0	-		5	3¾	1
3.30	3	9	5	5½	6	13	5	7½	15
3.35	4	6	6	0	7	9	5	11	18
3.40	4	6	5	14¼	7	15	5	15	26
3.45	4	6½	6	4	7	14½	6	2½	49
3.50	4	4½	6	6½	8	14	6	6	77
3.55	4	14	6	12¾	8	9	6	10	77
3.60	5	0	6	14½	8	14	6	13½	110
3.65	5	0	7	1	9	3½	7	1½	125
3.70	4	15	7	1½	10	2	7	5	148
3.75	5	2¾	7	8¾	9	14	7	8¾	134
3.80	6	9	7	13¾	10	7	7	12½	84
3.85	5	13	7	12½	11	5	8	0	62
3.90	6	11	8	4	11	0	8	4	36
3.95	6	13	8	5¼	10	8	8	7¾	23
4.00	7	7½	8	7½	9	13	8	11½	11
4.05	7	12	8	7½	9	5¼	8	15¼	3
4.15	9	11	9	11	-		9	6½	1
4.25	9	5	9	5	-		9	14½	1

Formula W = 4.62 x B - 9.79, where W = weight in pounds and B = biparietal diameter. Correlation co-efficient is 0.630 + 0.019. The standard error of prediction is thus 15 ozs.

moulding had disappeared: he came to the surprising conclusion that there was no sign of growth between the 36th week and term.

MOIR (1943, 1946, 1949, 1956) has devoted a great deal of work to x-ray cephalometry and believes it to be valuable. In an early series of 100 test cases and again in a later series he was accurate in forecasting the size of the biparietal diameter in 80 per cent of cases, the standard being an error of not more than 2 mm. above, or more than 1 mm. below the true measurement.

MOIR'S ingenious method for predicting the outcome of labour by plotting the foetal biparietal diameter on graphs showing the antero-posterior and transverse measurements of the pelvis at different levels is well known. WILLIAMS and PHILIPS (1946) and WILLIAMS and ARTHURE (1949) used this method and obtained a substantially correct prediction of labour in more than 90 per cent of cases, although in two thirds of these there was no evidence of disproportion.

CRICHTON (1952, 1953) came to different conclusions about the growth of the foetal head from those of previous workers. He measured the biparietal and occipito-frontal diameters in utero in 68 patients after the 36th week of pregnancy: those babies who were delivered not less than a fortnight later were x-rayed again 72 hours after birth. This study showed that the biparietal diameter increased from 1 mm. to 1.2 mm. per week. The rate of growth varied slightly from case to case and CRICHTON thought it was even possible for

the biparietal diameter to decrease in size in some cases after the 36th week. He found that growth of the foetal head continues after the 40th week, a fact of importance in the consideration of postmaturity.

MACDONALD (1952, 1954) gives similar results based on an entirely different type of study. He measured the head diameters of more than 1000 newborn infants with callipers and calculated the rate of growth by relating the size of the diameters measured to the age of the foetus as calculated from the maternal menstrual history. He concluded that the biparietal diameter increased by 1 mm. weekly in the last four weeks of pregnancy and continued to grow at this rate if pregnancy were prolonged beyond 40 weeks. The head size appeared to be related to the age, weight and sex of the foetus - males having the larger heads.

GLASS (1956) measured the biparietal diameter of 100 foetal skulls weekly by x-rays during the last four weeks of pregnancy and also showed an increase of 1 mm. per week during this period.

Despite the work which has been done on the subject, many obstetricians remain unconvinced of the value of x-ray cephalometry. SAVAGE (1951) was of the opinion that the head could not be measured accurately in utero. MENGERT and KORKMAS (1957) with an extensive experience of obstetric radiology, gave up measuring the head altogether

and contented themselves with a clinical impression as to whether the head was large, medium or small. BAIRD (1962) summarises modern practice by saying that cephalometry is only occasionally employed because of the difficulty of obtaining precise measurements. DONALD (1959) states, "Cephalometry by x-rays is often disappointing largely because it is difficult to be sufficiently certain of the distance of the foetal head from the x-ray tube and errors are magnified on the film" and also, "it is just in those cases where the head is not in the pelvis that cephalometry is most needed, yet in this instance the measurement is harder to obtain and consequently more unreliable".

CRICHTON (1952) performed cephalo-pelvimetry on 214 patients with clinical disproportion and came to the conclusion that it is not possible to be consistently accurate with cephalometry. According to CRICHTON, rotation of the head from a strict antero-posterior view by more than 30 degrees, as occurred in one third of his cases, increases the apparent length of the biparietal diameter so greatly that the measurement is impracticable.

LEWIS (1956) reviewing the subject, writes, "There are many who believe that the drawbacks to cephalometry are too great to make practical use of it".

All the doubts are about the accuracy of x-ray cephalometry. Of the clinical value of an accurate method of cephalometry there can be no doubt. To know the size of the foetal

head in cases of suspected disproportion and in malpresentations, to observe by repeated measurements, the growth of the foetal head in normal and abnormal pregnancy - these are matters of the greatest importance. In cases complicated by placental degeneration due to pre-eclampsia, chronic nephritis or hypertension, in cases of antepartum haemorrhage, in diabetes, or in any other condition where it may be necessary to terminate the pregnancy prematurely, knowledge of the size of the child, of which the size of the head is an index, would be of great value. A small foetus may be starving from placental failure; similarly, the presence of a well-grown foetus in a case of, say, hypertension, might lead the obstetrician to conclude that placental insufficiency was not a feature of the case. It is also desirable to assess the size of the foetus, particularly the foetal head, in cases of postmaturity. MACAFEE and BANCROFT-LIVINGSTON (1958) believe that the increasing size of the baby in prolonged pregnancy increases the risk of mechanical difficulty and that this is the main danger of prolonged pregnancy.

Until now, only two methods of assessing foetal size have been of use - radiography (with its technical difficulties and remote hazards) and abdominal palpation. The hand of the clinician remains his most useful tool but it can often err in judging the size of a foetus in utero. The thickness of the abdominal wall, the tension of the

uterus, the amount of liquor amnii and the presentation and attitude of the foetus are all liable to affect the estimate: even the most experienced observers may differ widely in their opinion and may all be mistaken. There is a place for a new, objective method.

THE THEORY OF ULTRASOUND

Vibrations whose frequency exceeds 20,000 per second are beyond the range of hearing and are, therefore, termed ultrasonic. Ultrasonic vibrations are pressure waves of the same nature as sound waves, differing only from them in those properties which are functions of frequency. Transmission of sound depends on the vibration of particles in the medium through which the sound passes, each particle being displaced sequentially as the wave passes through the medium. Elasticity in the medium provides a restoring force which tends to return each particle to its starting point. If the vibrating particles move in such a way that their acceleration towards the rest position is always directly proportional to their displacement from it, the wave is said to be "sinusoidal".

As a wave passes through a medium, there are, at any chosen instant, a number of points equally spaced along the direction of propagation at which the particles of the medium are at the same stage of displacement. The distance between such points is known as the "wavelength" in that medium. The wavelength varies with frequency and with the type of medium.

$\lambda = \frac{v}{f}$ where λ is the wavelength
v is the velocity of propagation
f is the frequency

For example, at a frequency of $2\frac{1}{2}$ million cycles per

second in water the wavelength is just over $\frac{1}{2}$ millimetre.

Propagation of Ultrasound.

This may be continuous or pulsed. Pulsed ultrasound means that the waves are generated by the transducer in short pulses with an interval between each. The most common type of pulse builds up rapidly and decays exponentially, in which case it is called a decayed or damped wave.

Speed of Ultrasound.

The speed of ultrasound in solids depends upon the equation

$$V = \sqrt{\frac{E}{D} \frac{1-p}{(1+p)(1-2p)}}$$

where V = velocity.
E = Young's modules - a relation between the stress intensity and the resulting strain.
D = density of the solid.
p = Poisson's ration, the relation between a change in width and the change in length which caused it.

In liquids and gases the equation reads -

$$V = \sqrt{\frac{K}{P.\ Bis}} = \sqrt{\frac{1}{P.\ Bad}}$$

where K = ratio of specific heat
P = density
Bis = compressibility at a constant temperature in liquids.
Bad = Adiabatic compressibility in gases.

Transmission of Ultrasound through Different Media.

When a beam of ultrasound crosses an interface between two substances of differing specific acoustic impedance (which is defined as the product of the density of the material and the velocity of the sound wave in it) five phenomena can occur, namely:-

1. Reflection. Some of the energy is reflected at the interface, the amplitude of the reflected waves being proportional to the difference of the two acoustic impedances divided by their sum (Rayleigh's Law). Therefore, the greater the difference in specific acoustic impedance between two adjacent materials the higher will be the percentage of energy reflected.

2. Refraction. This occurs particularly where the ultrasonic beam is not at right angles to the plane of the interface.

3. Attenuation. Much of the energy which is not reflected is transmitted to the second medium but is somewhat attenuated.

4. Generation of Heat. Some of the energy may be absorbed and produce heat.

5. Cavitation may be produced if considerable energies are present at lower ultrasonic frequencies and usually develops only when the ultrasound is applied continuously.

Reflection is the most important phenomenon for diagnostic purposes and it is on the recording of echoes

from reflecting interfaces that the work on foetal cephalometry is based.

This effect is small, but can be greatly magnified by the phenomenon of resonance. If the crystal is excited by an alternating voltage, the crystal vibrates. If now the frequency of alternation is made equal to one of the natural frequencies of the crystal - a frequency at which it would "ring" if tapped - the amplitude of vibration is much increased.

The Generation of Ultrasound.

The best method of producing ultrasound of high frequency is by the inverse piezo-electric effect. The piezo-electric effect was discovered by P. & J. CURIE in 1880: they found that certain crystals would develop an electrical charge when a mechanical pressure or tension was applied. The inverse piezo-electric effect was described by LIPMANN in 1881: a crystal could be distorted by placing an electric charge across it.

A crystal of quartz or barium titanate can be subjected to an electrical charge so that it produces ultrasonic vibrations. When the crystal vibrates, transmission takes place in both directions perpendicular to its faces. If the crystal is backed with a material of low ultrasonic transmission, such as air, the maximum transmission will be in a forward direction. If a crystal transducer is placed on a dry surface, very little energy will be transmitted through the interface because

of the intervening air present. A coupling medium is therefore required. (In the work to be described, olive oil is used as the coupling medium between the barium titanate transducer and the patient's skin.)

When ultrasound generated by a crystal as described is reflected from an interface, the reflected energy can cause another suitably placed crystal to vibrate and by means of the direct piezo-electric effect this energy is converted to an electrical signal which can be picked up and amplified. This is the basis of the transducer system used in the present work.

MEDICAL APPLICATIONS OF ULTRASOUND

Ultrasound has been used in medicine both for treatment and diagnosis.

Its first use as a form of treatment depended on its ability to produce heat in body tissues. This effect was first noted by FREUNDLICH et al. (1932).

Ultrasound has been widely used as a form of physiotherapy, like short-wave diathermy. LEHMANN et al. (1954), DE PREUX (1952) and MONCUR (1957) have used ultrasound in this way.

The effect of ultrasound on selected areas of the brain was recognised by ZUBIANI (1951), who, after experimenting with dogs, carried out leucotomy on cases of general paralysis of the insane and schizophrenia, with promising results. Further work in this field was done by FRY et al. (1954 and 1955) and BARNARD et al. (1955). The effect of ultrasound on brain tissue will be considered in more detail below.

ARSLAN (1953) originated what has proved to be one of the most fruitful therapeutic uses of ultrasound: this is in the surgery of Ménière's disease, to destroy the functioning of one of the sets of semicircular canals. Vestibular function takes from two to six weeks to disappear following the operation so that it appears that the effect is not due to heat alone. More recently, JAMES et al. (1960) have used ultrasound in the treatment of the Ménière syndrome with satisfactory results.

It is the diagnostic applications of ultrasound which are of chief interest in connection with the present work.

DUSSIK (1942) and DUSSIK et al. (1947) first applied ultrasound for diagnosis. They studied the variations in an ultrasonic beam passing through the cranial cavity and claimed to be about to outline the ventricles. FRENCH et al. (1950) were able to locate tumours within the substance of brains removed at post mortem.

Instead of continuous ultrasound, pulsed ultrasound was now being used and the echoes were studied on a cathode ray tube where they were represented as amplitude deflections from a base line. This was known as A-scope presentation. WILD (1950), WILD and NEAL (1951) and REID and WILD (1952) attempted to use ultrasound as a means of diagnosing cancer, particularly in the breast. Later WILD and REID (1956) claimed great accuracy with this technique, although to that date they had only examined 77 cases.

HOWRY et al. (1954) gave illustrations showing considerable detail obtained on ultrasonic examination of various tissues. HOWRY (1955) published further illustrations showing a cross-section of the neck and also the normal abdomen and the abdomen with ascites and secondary deposits of carcinoma in the liver. KIKUCHI et al. (1957) developed the plan-position-indicator (P.P.I.) display, immersing patients in water and traversing the surface with the transducer set on rails.

EFFERT et al. (1957), using "A-scope", studied the heart and

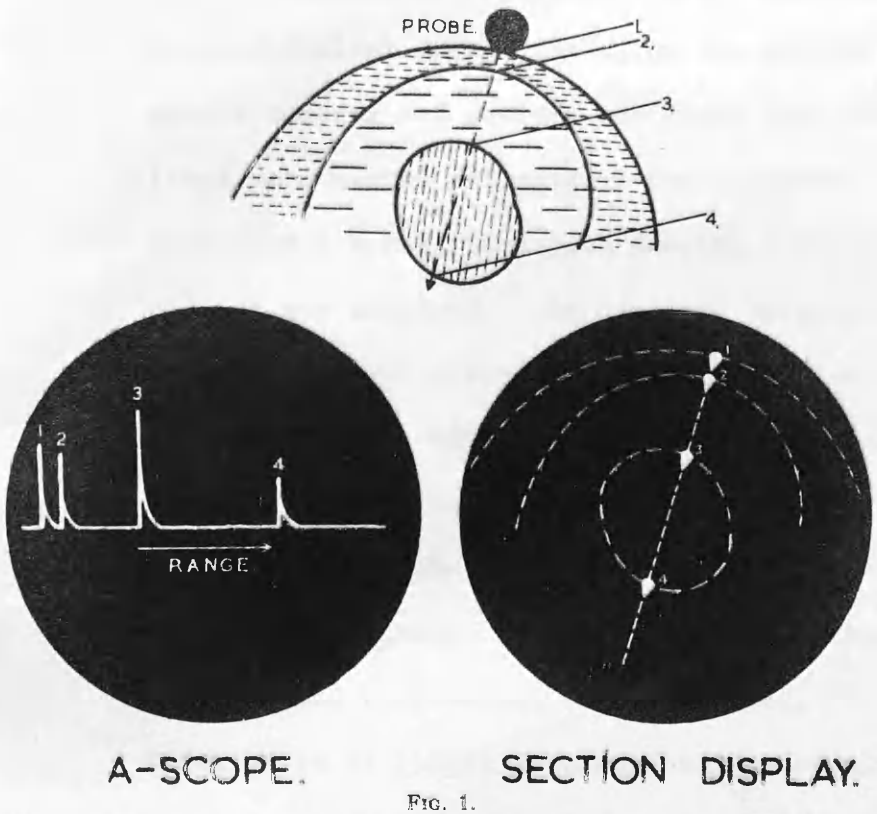


FIG. 1.

Diagram showing how interfaces at 2, 3 and 4, are represented by A-scope (left) and cross-sectional display (right).

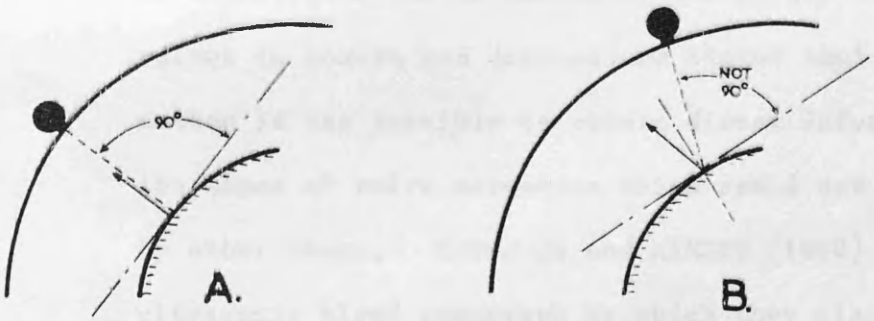


FIG. 2.

Ultrasonic beam must be perpendicular to interface (as at *A*) for echo to return to probe.

FIGURE 1. Types of Ultrasonic display used for medical diagnosis. A-scope presentation (the type used for cephalometry) is limited to one dimension, whereas section or P.P.I. display can be two-dimensional if a multiple angle scanning technique is used.

(Illustration from DONALD & BROWN (1961))

were able to demonstrate pericardial effusions. DONALD et al (1958) developed the use of ultrasound as a diagnostic aid in obstetrics and gynaecology. They investigated intra-abdominal masses including the gravid uterus, various pelvic tumours and ascites and found that masses containing fluid were easily but crudely demonstrated. They have developed a P.P.I. technique whereby sectional views of the abdomen are obtained. In addition they investigated the possible harmful effects of their method and found them to be negligible. BAUM and GREENWOOD (1958, 1960) also used a P.P.I. display to obtain considerable soft tissue detail in the study of the eye: by this means they were able to demonstrate detached retina, tumours, vitreous haemorrhage, cataract and radiolucent foreign bodies.

SATOMURA et al (1960) developed a form of ultrasonic cardiograph. Using continuous ultrasound they were able to investigate the movements of the atria, ventricles and valves in health and disease and stated that with this method it was possible to obtain direct information about the times of valve movements which could not be obtained by other means. SATOMURA and KANEKO (1960) described an ultrasonic blood rheograph by which they claimed it was possible to detect changes proportional to the velocity of flow of the blood in arteries and veins: they compared their results with a simultaneously recorded electrocardiogram and found the method useful in estimating the degree of arteriosclerosis present.

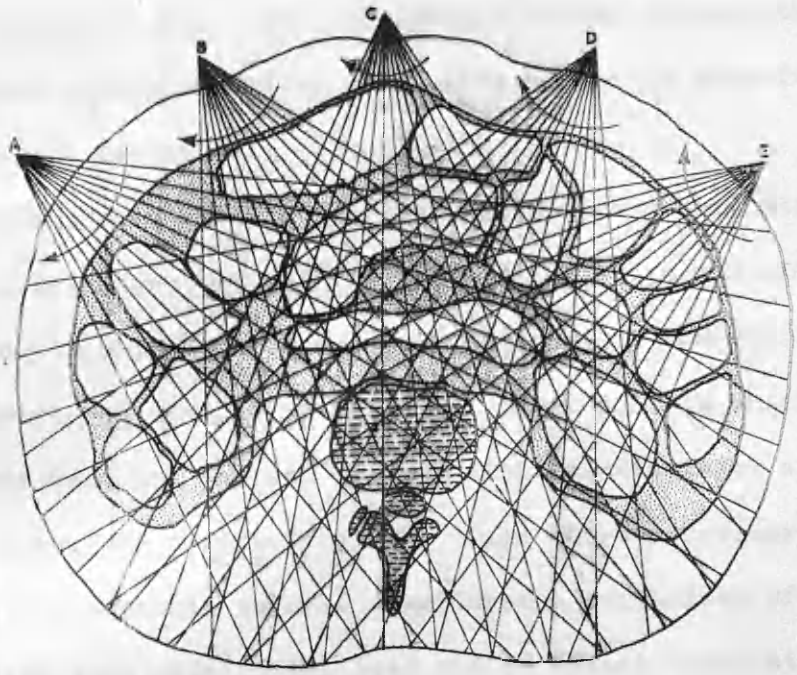


Fig. 3. Scanning pattern. A, B, C, D and E are the origins of five typical overlapping sector scans, each of which has a mean direction towards the centre of the cross-section. In practice, a sector scan is made every 5° or so around the skin, so that each tissue interface is scanned from a large number of different angles

FIGURE 2. Compound Sector Scanning
This illustrates how a transverse section of the abdomen is scanned by a probe which is made to rock through many scanning angles. This method is used by DONALD for gynaecological diagnosis.

(Illustration from DONALD & BROWN (1961))

Diagnostic work on the skull is especially interesting for the purposes of the present study. LEKSELL (1956) used "A-scope" for examination of the skull to assist in the diagnosis of intracranial haemorrhage by detecting deviation of echoes obtained from the midline structures of the brain. In a second paper LEKSELL (1958) put forward the theory that the pineal body was the source of the midline echo.

KIKUCHI et al. (1957) observed a tumour through the scalp and also pulsating echoes which they assume to come from the wall of the ventricle.

VLIEGER and RIDDER (1957) obtained almost complete success in detecting the midline echo in the brain and displacements in its position: they quote 47 cases. GORDON (1959) developed a modification to an instrument in which two probes are used and the echoes from each are displayed simultaneously, one upwards from the trace and one downwards, whereby it is possible to make simultaneous comparison of the echoes from each side of the head and so detect immediately any displacement of the midline.

JEFFERSON (1959) used an instrument with GORDON'S modification and in 42 out of 50 cases the ultrasonic findings were confirmed by x-ray pictures.

NEWELL (1960) reported a series of 106 cases at St. George's Hospital in which the midline structures of the brain had been detected with an accuracy of 85 per cent. He used a

frequency of 2.5 megacycles: a single crystal of barium titanate was used both as transmitter and receiver. NEWELL thinks that the midline echo is due to the superior longitudinal fissure separating the two hemispheres of the brain. Later TAYLOR et al (1961) reported that the St. George's Hospital series had increased to 280 cases and that the presence or absence of a space-occupying lesion in the brain had been reported with an accuracy of 87 per cent. JEPPSSON (1961) has produced a most impressive and detailed study on this subject of "echoencephalography", following the pioneer work of his former chief, LEKSELL. JEPPSSON defines the source of the midline echo on the basis of observations made at clinical echoencephalography and on the basis of an experimental investigation using removed, fresh brains from children as well as adults; he concludes that the calcified pineal body constitutes the primary source of the midline echo in adults, while in children the walls of the third ventricle, the posterior part of the septum pellucidum and part of the longitudinal cerebral fissure are the structures responsible for the midline echo. JEPPSSON presents the results of echoencephalography in a clinical series comprising 579 cases, subdivided into a "tumour group", a "trauma group" and a "vascular group"; the accuracy of the method is estimated at 97.9 $\pm$ 0.6 per cent. Examples are also given of the usefulness of echoencephalography for checking postoperative progress with a view to disclosing haematoma and brain swelling.

Summarising the advantages of echoencephalography JEPPSSON states that it is quick, simple and accurate and can be performed in the consulting room; that it is harmless, causing no inconvenience or discomfort to the patient; that the examination is infinitely repeatable, making the method eminently suitable for checking clinical progress; that it gives an adequate foundation for immediate treatment in emergency cases and that the examination is easily performed in small children or in restless or agitated patients.

In another field, the work of BERLYNE (1961) is interesting as an example of the use of ultrasound to make measurements in living tissues - the object also of cephalometry. BERLYNE used an "A-scope" presentation to locate the lower pole of the kidney and to measure ultrasonically its depth from the surface in 20 patients before renal biopsy was performed: in 18 of the 20, kidney depth was determined to within 0.5 cm. In this work, calibration in units of distance was achieved by preliminary experiments on the cadaver, a calibration curve being made to relate the depth of tissue in centimetres to arbitrary units marked on the cathode ray oscilloscope.

EFFECTS OF ULTRASOUND ON THE BRAIN AND NERVOUS SYSTEM

As foetal cephalometry by ultrasound involves the passage of a beam of pulsed ultrasound through the brain of the unborn child, it is of great importance to study the effect of ultrasound on brain tissue.

In diagnostic work it is most important that the power level of ultrasound should be kept very low to ensure that neither immediate nor cumulative damge is done to the patient: as will be shown, it appears that, at the powers used for diagnosis - around 1/1000 W/sq.cm. - the ultrasound appears to have no effect at all on the body. However, if the power level is increased a million times, to 1000 W/sq.cm., and the ultrasound is focused into a small volume, destructive effects occur. The ultimate physical reason for the destructive effect of ultrasound on tissues remains obscure and it appears that neither heat nor cavitation is solely responsible.

As is well known, the destructive effects of ultrasound are used in neurosurgery and have been the subject of much intensive research, particularly by W.J. FRY and his colleagues at the University of Illinois. The mass of detailed work they have produced on this subject has been reviewed by FRY et al (1960) and FRY & DUNN (1962).

From extensive experimental animal studies they established the following facts, upon which the use of high-intensity ultrasound in neurosurgery depends.

(a) By focusing the ultrasound it is possible to confine the induced changes (permanent or temporary) to a desired array of deep brain sites without corresponding effects on intervening brain tissue. This effect may be compared to the heat of the sun focused through a burning glass which will char paper at the focus but not elsewhere.

(b) Lesions of almost any desired shape and size can be produced by placing the focus successively at sites in an appropriate array.

(c) Selective action on specific tissue components can be accomplished by accurate control of the irradiation parameters and the temperature of the tissue.

The selectivity which ultrasound displays in the central nervous system is extremely useful in investigations of the complex anatomical structure. Post-mortem microscopic examination of sound-irradiated tissue has shown that, within the brain blood vessels are the most resistant element and that it is possible to destroy selectively the fibre tracts of white matter without damaging grey matter. Thus the vascular system can be left intact and functioning while the neural elements are destroyed, thus avoiding the danger of haemorrhage, and irreversible changes may be produced in white matter without disruption of nerve cell bodies in grey matter.

(d) No delayed cumulative action is produced in intervening irradiated tissue, so that the ultrasound may

pass on its way to the focus any number of times without producing undesirable changes.

The success of surgical techniques depends entirely upon placing the ultrasonic focus at the desired site in the brain and on controlling the exposure exactly. Very complex and precise apparatus is therefore required. The only accessory piece of conventional surgery in the treatment is, however, the removal of a single small portion of the vault of the skull. This is done because of the great absorption of ultrasound in bone. The scalp is replaced over the aperture and, after healing has taken place, the ultrasonic treatment is given through the intact skin. Structures on both sides of the brain may be modified by ultrasound directed through this single aperture in the skull.

Ultrasound has been used in this way with favourable results in PARKINSON'S disease, choreo-athetotic cerebral palsy, cerebellar dyssynergia, parasthesia following cerebrovascular accidents ('Thalamic' syndrome) and to relieve "phantom limb" symptoms after amputation. In addition it has been used to modify pituitary function in cases of extensive and metastasing breast carcinoma.

The wavelength of sound in the propagation medium and the aperture angle of the focusing system are the important factors determining the "minimum volume" of tissue which can be affected by a single exposure. Since the minimum realizable dimensions of the focal

region decrease as the frequency increases, it is desirable to operate at frequencies where the wavelength is of the order of 1 millimetre or less. FRY & DUNN (1962) state that most of their work on experimental animals and humans has been at a frequency of 1 m.c. where the wavelength of sound in brain tissue is approximately 1.5 millimetre, but that a frequency of 4 m.c. it is possible to produce lesions only a few hundredths of a cubic millimetre in volume. FRY et al (1960) quote 1000 watts per square centimetre as an example of the power level used in their work.

There have been numerous investigations to discover at what intensities tissues are damaged. Tissue destruction is believed to start at an intensity value of 1-2 W/sq.cm. for continuous ultrasound and 1-2 W/sq.cm. mean intensity for discontinuous (pulsed) ultrasound. This is one of the reasons why pulsed ultrasound is used in diagnosis as it permits far greater impulse intensities and still carries a negligible risk of tissue destruction. BALLANTINE, BOLT, HUTER and LUDWIG (1950) exposed two dogs to continuous-wave ultrasound at a frequency of 2.4 Mc/s, directly applied to the skull. The one case was irradiated with an intensity of 3 W/sq.cm. for 11½ minutes; the other with 1.5 W/sq.cm. for 15 minutes. None of the animals had brain lesions on histological examination. In the same way a cat was exposed to

15 W/sq.cm. for 5 minutes at a frequency of 800 Kc/s; it received a superficial necrotic lesion of the skin and subcutaneous tissues but showed no neurological symptoms suggestive of a brain lesion. Two humans were also irradiated with continuous-wave ultrasound applied directly to the skull at a frequency of 800 Kc/s with an intensity of 2 W/sq.cm. for 9 seconds, with simultaneous electro-encephalographic monitoring. Afterwards the persons tested complained of slight pain in the scalp; no changes were observed in the electroencephalogram.

HUTER and BOLT (1951) reported the effects of continuous-wave ultrasound on the peripheral nerves of anaesthetised animals, using intensities of up to 45 W/sq.cm. Provided that the temperature was kept down by cooling, the nerve was only stimulated, giving action potentials, which were recorded. They drew the conclusion that ultrasound damage depends on the heating effect resultant from irradiation and, summing up the investigations, they held 1 W/sq.cm. as being safely below the damage threshold of continuous-wave ultrasound. FRENCH, WILD et al (1951) also investigated the problem as applied to pulsed ultrasound at a frequency of 15 Mc/s with a mean intensity of 1.3 W/sq.cm. They used animals (cat and rabbit), laying bare the cortex and exposing it to ultrasound as above for 20 minutes. Histological investigations, done at intervals ranging

from 4 hours to 8 weeks could not disclose any lesions.

DONALD et al (1958) performed an experiment to ascertain possible harmful effects of the diagnostic use of pulsed ultrasound which is of particular relevance to the work on foetal cephalometry as the ultrasonic flaw detector used was of the same type. The brains of newborn kittens were chosen for experiment because their susceptibility to damage was increased by the lack of myelination. Four day old sibling kittens were used, two being exposed to ultrasound and two used as controls. All four kittens were anaesthetised and two were exposed to pulsed ultrasound from the flaw detector for an hour. Two kittens (one experimental and one control) were killed with coal gas 24 hours after the start of the experiment. The other two were left under the mother's care for three weeks, during which time the experimental kitten developed in advance of its sibling: at the end of this period these kittens were also killed. Careful histological preparations of the brains were made. In the 24 hour experimental kitten, signs of cavitation, coagulative necrosis, localised hyperanaemia, haemorrhages and chromatolysis were looked for: the brain of the 3-week kitten was examined for any evidence of patchy cell destruction, neuroglial scarring, axonal degeneration and localised lack of myelination.

All these tests were completely negative, and the brains

of the experimental kittens and their respective controls were in every way comparable.

On the basis of these findings it was concluded that the exposure of the kittens to more than thirty times the dose of ultrasound necessary in its diagnostic use produced no detectable neuropathological change.

GORDON (1959) gave the opinion that to bring about any cell damage at all, it is necessary to use continuous-wave ultrasound with an intensity of the order of a few W/sq.cm., with an exposure time lasting for several minutes and without any intervening bone tissue. He pointed out that the current diagnostic units use an intensity of a few microwatts and very short exposure times and that the amount of energy used is far below the damage threshold values referred to above.

The relevant data for the apparatus used in the work on foetal cephalometry are as follows. The average electrical input to the probe is 0.75 milliwatt. The area of the probe at present used is 1.5 square centimetres. Assuming 100 per cent efficiency, the average acoustic power would be 0.5 milliwatt per square centimetre. It is, in fact, probably much less. The The exposure time varies with different cases but is usually less than 2 minutes.

THE PRINCIPLE OF ULTRASONIC FOETAL CEPHALOMETRY

In 1959, DONALD, having noted that clear echoes could be obtained from the foetal head in utero, decided to apply ultrasonic techniques to the measurement of the head, DONALD & BROWN, 1961). To do this, he reverted to an A-scope technique as this conveniently reproduced the echoes from the ultrasonic beam in such a way that they could be measured. The basis on which the measurements are made is as follows.

The foetal head, viewed in transverse section is roughly ovoid, with only two sets of parallel surfaces - between the brow and the occipital region and between the two parietal eminences. When an ultrasonic beam passes through the foetal head, echoes are received from the skull and sometimes from the falx cerebri: the brain substance itself contains no pronounced discontinuities in density and therefore no echoes appear. Echoes from the skull will be maximal only when the ultrasonic beam is at right angles to the skull+ and therefore clear echoes from both sides of the skull will only be obtained when the beam traverses parallel surfaces at right angles - i.e. across the occipito frontal or biparietal diameters.

+ HOWRY (1955) and DONALD et al. (1958) noted that even quite small angular displacements from the perpendicular in the incidence of the ultrasonic beam produced very great differences in the amplitude of the reflected echo. HOWRY calculated that an angle of 6^{o} off the perpendicular reduced the amplitude of the deflected echo to a tenth, and 12^{o} reduced it to a hundredth.

Ultrasound passing across these diameters gives echoes of roughly equal intensity from both sides of the skull, while, if the ultrasound passes across other skull areas, it will be reflected off and the echoes will not be reproduced. (Fig. 3).

The validity of this theory was tested experimentally. A dry foetal skull was mounted on a rod perpendicular to its base and the other end of the rod was attached to a protractor so that rotation of the skull about a vertical axis could be measured. The skull was then immersed in a perspex tank filled with water. The probe of the ultrasonic flaw detector was then applied to the surface of the tank, acoustic coupling being obtained with olive oil, and the A-scope patterns obtained from the skull as it rotated were studied. It was confirmed that clear echoes were obtained from both sides of the skull only when the ultrasonic beam traversed the biparietal and occipito frontal diameters.

These findings have since been corroborated by work on the heads of infants during the neonatal period.

It is now universally recognised that, in the vast majority of cases, the foetal head, during the later weeks of pregnancy, lies with its long axis in the transverse diameter of the pelvic brim - an observation made by SMELLIE (1752), although frequently, and wrongly, contradicted thereafter. The biparietal diameter, therefore, is at right angles to the surface of the

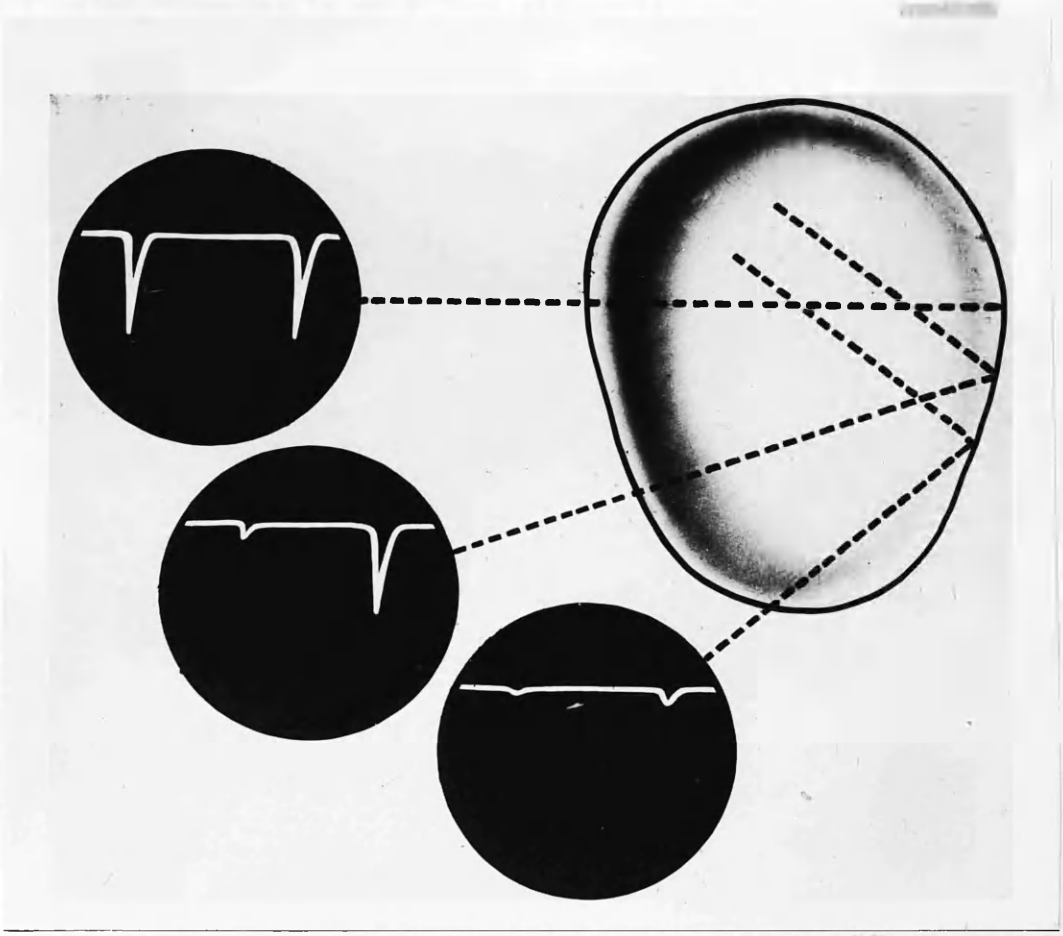


FIG. 3. Superior View of Skull with echo display. Echoes have simultaneous maximum amplitude when the beam of ultrasound is directed along the biparietal diameter.

maternal abdomen and parallel to an ultrasonic beam directed perpendicular to the abdomen. The occipito-frontal diameter is much less accessible to ultrasonic examination because of its lateral position and is so much larger than the biparietal that it is unlikely to be confused with it.

The biparietal diameter is of greater obstetrical importance than the occipito-frontal, for it is the diameter which must pass through the narrowest part of the pelvic inlet. It is said by BAIRD (1962) to measure 8.7 centimetres at term, while GREENHILL (1955) quotes 9.5 centimetres as the normal measurement. The occipito frontal diameter at term normally measures 11 centimetres or a little more.

To obtain, by ultrasonic means, a measurement of the biparietal diameter it was necessary to measure the time interval between the echoes obtained from the near and far sides of the foetal skull. This time interval could then be converted into a measurement of the biparietal diameter in centimetres, if the velocity of sound in the tissues were known or assumed.

In order to measure the difference in the time of flight of sound pulses from one side of the head to the other, a special ranging unit was constructed, as will be described below. At first measurements were made from photographs of the A-scope trace, but later the measurements were obtained by setting electronic markers

on the echoes obtained.

In the first series of cases, when echoes from both sides of the foetal skull appeared simultaneously and above a preset threshold the A-scope display was automatically photographed. There were, however, many errors in interpretation and measurement of the photographs. The foetus in utero displays considerable mobility, unless the foetal head is engaged in the pelvis. Maternal respiratory movements also cause alteration in the position of the foetal head. Careful and repeated scanning is necessary to confirm that the A-scope displays distinct echoes from each side of the foetal head, in which case it can be assumed that the biparietal diameter has been found. It is our practice to study the A-scope patterns very critically, setting the electronic cursors on echoes as they appear, but only making actual measurements where the picture is unequivocal. It is no longer our practice to phorograph the A-scope trace.

DETAILS OF TECHNIQUE

The apparatus used is a modified commercial ultrasonic flaw detector (The Kelvin Hughes Mark IV) with "A-scope" presentation and a ranging unit to measure accurately the time of flight of a pulse of sound reflected from a density discontinuity. (Fig. 4).

The frequency used for cephalometry is $2\frac{1}{2}$ megacycles per second, the highest available, which was very suitable because the theoretical resolution obtained was adequate

FIG. 4. Apparatus used for foetal cephalometry by ultrasound.

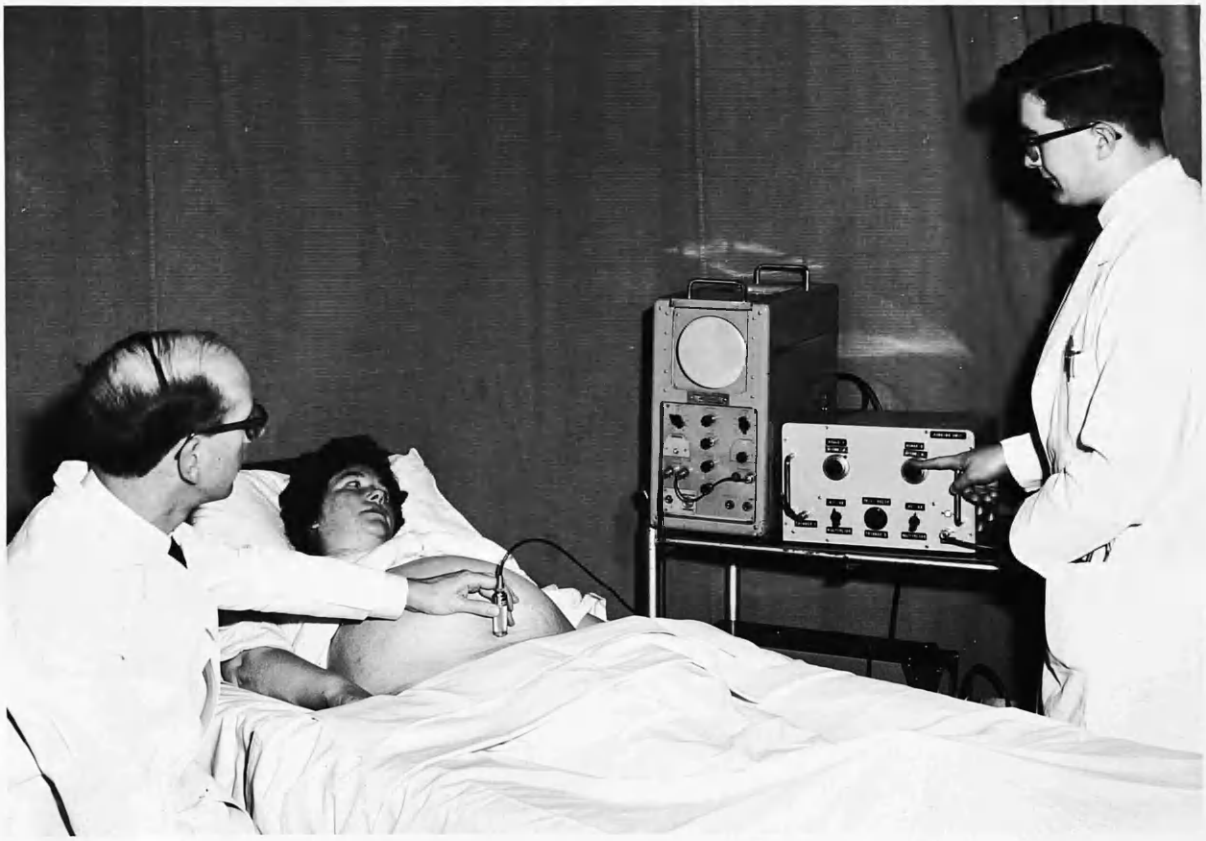


FIG. 4 (a). The apparatus in use.

and the power level low.

An electrical pulse is applied at mains frequency to a thyratron circuit tuned to $2\frac{1}{2}$ megacycles per second. The damped oscillation produced by this circuit energises one of a pair of barium titanate crystals mounted side by side in the probe unit. One of these two piezo-electric transducer crystals is used for transmitting and one for receiving. Each is a barium titanate rectangle 10 millimetres by 7 millimetres and the two are placed with their 10 millimetre sides contiguous. The transducers lie on a conducting layer on a "Perspex" block one inch thick whose opposite side forms the face of the probe which is in contact with the patient's skin. The transmitting transducer is "air-backed". At each pulse it vibrates mechanically for a very brief interval at a frequency determined by its elastic properties and its thickness. For a frequency of $2\frac{1}{2}$ megacycles the thickness of the crystal requires to be about 1 millimetre. The output of the transducer then is a highly damped $2\frac{1}{2}$ megacycle per second ultrasonic oscillation which is radiated from the transducer surface in a narrow pulsed beam.

Density discontinuities in the path of the beam give rise to reflection of the ultrasound and if the discontinuity has a surface parallel to that of the transducer some of the energy is reflected back along the probe axis and strikes the receiving transducer crystal. A small voltage

is generated by the piezo-electric effect, amplified and displayed as vertical deflections or "blips" on a horizontal linear time-base sweep on the cathode ray tube, the propagating source of ultrasound being represented at the origin of the sweep. The time base of the oscilloscope is also started by the master pulse firing the thyratron. Thus the reflecting surface of a density discontinuity is indicated on the oscilloscope trace as a blip displaced along the trace by a distance proportional to the time between transmission of the ultrasound pulse and reception of the echo. (Fig. 5).

This distance is measured by the ranging unit as follows:- The master pulse from the flaw detector starts the run-down of a linear phantastron sweep generator, which drives a multiar comparator. The output of this circuit is a very short pulse applied as "Z" (brightness) modulation to the oscilloscope tube in the flaw detector; a reference voltage for the comparator is generated by a potentiometer across a stabilised voltage supply. Thus a bright spot superimposed on the A-scope display is positioned by a potentiometer which can be calibrated in units of time. A second similar pulse generator is also incorporated. This can be triggered either by the master pulse or by the pulse from the first timing unit. Thus two bright markers are available for measurement on the A-scope trace and are positioned by two potentiometers scaled in units of time. If the material under examination is

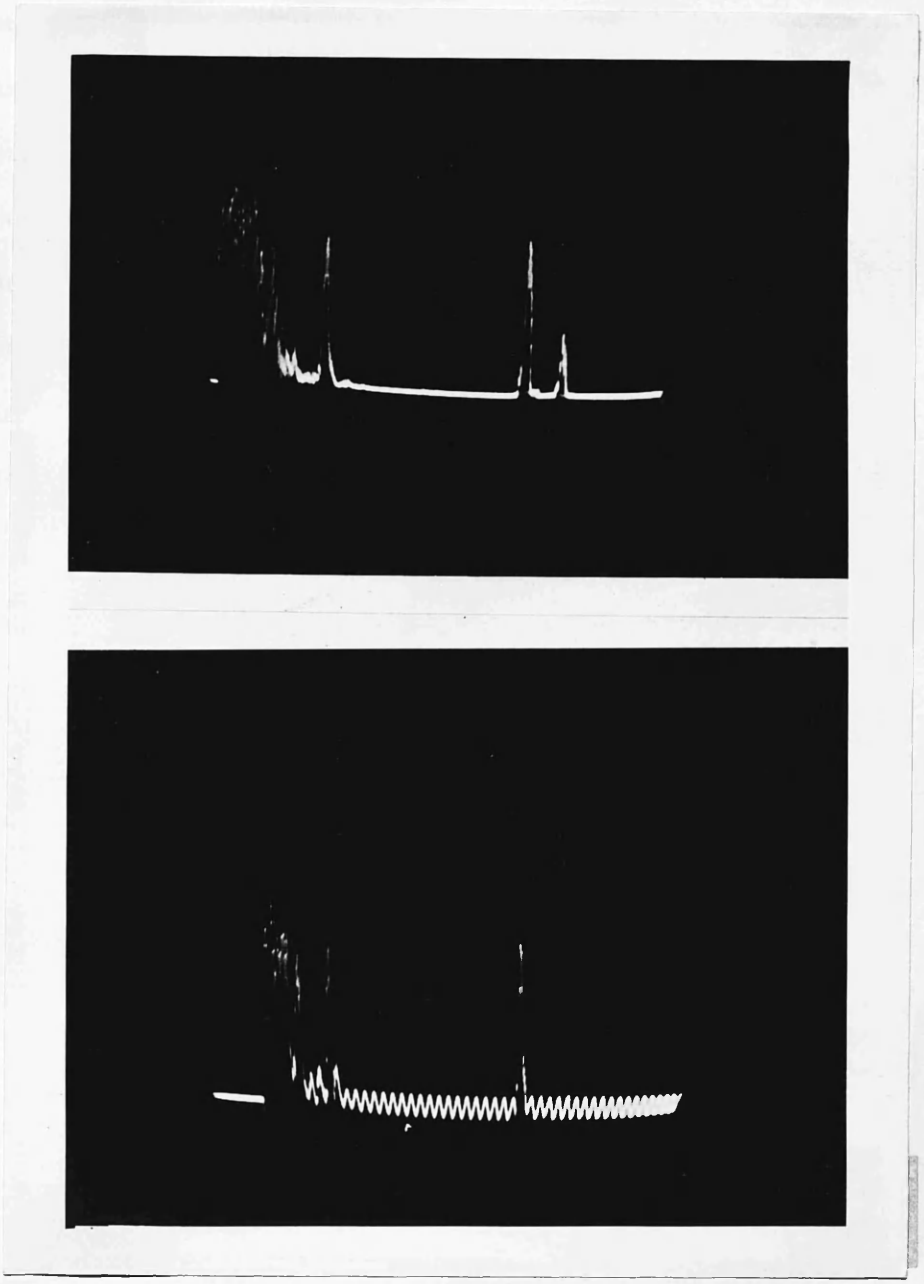


FIG. 5. A-scope appearances.
These are the typical appearances obtained when the beam of ultrasound is directed along the biparietal diameter. The echo on the extreme right of the top illustration is that obtained from the posterior uterine wall. The lower illustration shows a calibrated time base.

homogeneous (i.e. the velocity of the sound pulses is constant) the time measurement will be proportional to the distance and the measuring dials can be scaled in units of distance. (Fig. 6).

In order to make the record as fundamental as possible, it is now our practice to record the measurement in time as this obviates any error due to assuming or calculating an incorrect speed of ultrasound in the tissues.

ULTRASOUND FLAW DETECTOR USED FOR FOETAL CEPHALOMETRY

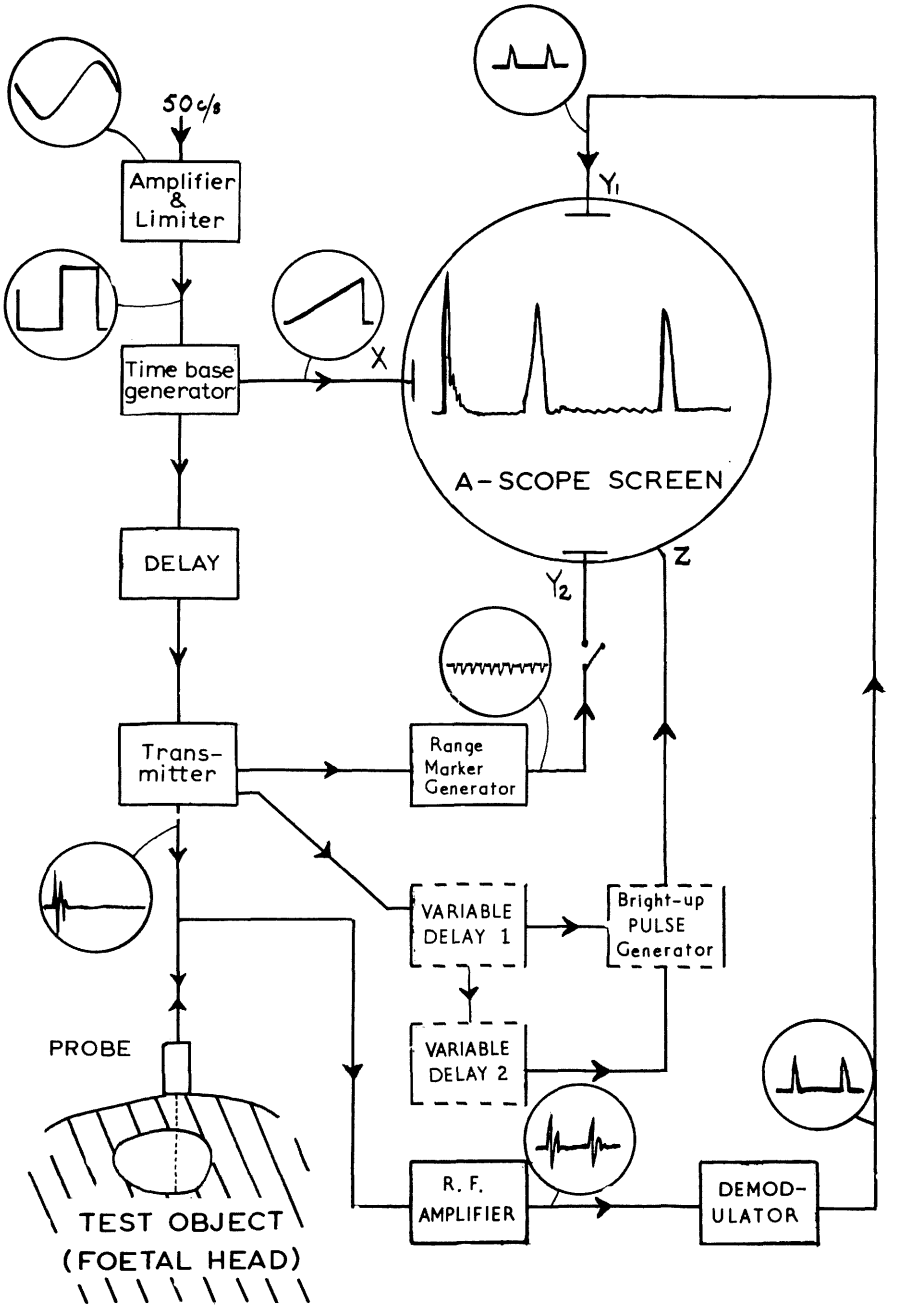


FIG. 6. Diagram of Apparatus.

DEVELOPMENT OF THE METHOD

As has been shown, the ultrasonic pulse reflection method for the detection and measurement of the foetal biparietal diameter depends on the reception of echoes from the near and far sides of the foetal head. Echoes received from the far side take a longer time to return to the probe than those from the near side and both are represented on a cathode ray tube in the same spatial relation as the echo-producing surfaces. With a calibrated time base it is then possible to measure the time of flight of sound pulses from the probe to the different echo-producing surfaces.

The types of probe available are not suitable for measurements close to the probe surface, but this is of little importance as the proximal surface of the foetal head is usually several centimetres distant.

It is believed that the echo-producing surfaces of the foetal head are the sides nearer to the probe of the proximal and distal skull margins. The time interval measured between echoes representing the opposing sides of the foetal head is therefore that for a pulse of sound to pass from the surface nearer the probe of the proximal side of the skull through a thickness of skull and the brain to the nearer surface of the distal skull margin where it is reflected. This time is less than that which would represent the actual biparietal diameter by the

thickness of the scalp at the proximal side of the skull plus the thickness of scalp and skull at the distal side.

To obtain a reading of the length of the biparietal diameter in units of distance, the speed at which ultrasound travels in the foetal head requires to be worked out. With this end in view, two experiments were designed -

(1) To compare the time taken by ultrasound to traverse the biparietal diameter in the neonate with the actual measurement of that diameter.

(2) To estimate the proportion of the various components - scalp, skull and brain - in the foetal head.

The details of these experiments are given below: as a result of them it has been possible to eliminate some of the errors present in earlier work. In the earlier work (before October, 1961) echoes from the foetal head were compared in position with those from moveable targets in a water tank. In this way the measurement of the biparietal diameter could be found on the assumption that the velocity of sound in the head is similar to that in water - an assumption which has been frequently made in ultrasonic work with body tissues. Measurements obtained in this way on the foetus were often confirmed by a single calliper measurement made after birth. Quite good agreement was usually obtained between foetal and external measurements if a growth of 1 to 2 millimetres per week in

the biparietal diameter was allowed. However, this method included two important sources of error, both of which resulted in an estimate of the biparietal diameter which was too small -

(a) It ignored the fact that the ultrasound measurement did not take account of the thickness of the scalp at the near side of the head and the thickness of skull plus scalp at the far side of the head. These thicknesses are not negligible as was first thought, but in each case are between 1 and 2 per cent of the biparietal diameter.

(b) The velocity of ultrasound in the head is appreciably higher than that in water. The velocity in water at 20°C is about 1480 metres per second whilst in skull bone it is 3360 metres per second (THEISMANN et al 1949; FRY and DUNN, 1962) and in brain tissues 1515 metres per second (LUDWIG, 1950; EDLER et al 1960). In a head with normal skull/brain thickness the average velocity would be about 1540 metres per second.

COMPARISON OF ULTRASOUND AND CALLIPER MEASUREMENTS IN THE NEONATE

In October, 1961, a more accurate calliper, (Fig. 7.) incorporating a vernier scale, was obtained and a series of measurements was made on neonates to obtain the biparietal diameter by ultrasonic and calliper methods. At the same time an electronic cursor was constructed to enable more

FIG. 7. Calliper used for measuring the biparietal diameter in the neonate, with ruler incorporating vernier scale.

accurate measurements to be made on the echoes obtained from the foetal and neonatal head. This cursor measures on the A-scope the time of flight of the sound pulses and can be adjusted to an accuracy of 0.05 per cent of the maximum time that can be measured, which is 200 microseconds, (μs), but because of non-linearities it is doubtful whether an accuracy of 0.5 per cent is obtained over the whole range.

The ultrasonic results were obtained by placing the small probe unit directly on the infant's parietal eminence. Olive oil was smeared liberally on the probe surface and also onthe side of the child's head, smoothing down the hair and eliminating air bubbles. Normal infants, in the post-natal wards with their mothers, were chosen for this examination which did not disturb the babies at all - some did not even rouse from sleep. They were held in their mothers' arms during the examination. The electronic cursors were set, the proximal one on the echo produced by the probe surface and the distal one on the echo produced by the far side of the foetal skull, which could usually be sharply defined by a little manoeuvring of the probe. Quite often, echoes from midline brain structures could also be seen. The calliper measurement of the biparietal diameter was then made, without previous knowledge of the reading obtained by ultrasonic examination.

The results of this series are summarised below.

Number of cases examined - 72.

Average external biparietal diameter $\bar{d}$ = 9.30cm.
(measured by calliper)

Average time measured by ultrasonic $\bar{t}$ = 117.8 us.
reflection

From these data, a scale factor $\bar{d}/\bar{t}$ can be applied to individual measurements of time (t) to predict the biparietal diameter (d).

i.e. d predicted = 0.079 t.

Where d is in cm., t in us.

Also the error E is /d - d predicted/

i.e. E = med. d - d p.

These errors were calculated and show a distribution as follows -

Error			Number of Cases
0	/E/	0.5mm	31 (43%)
0.5mm	/E/	1.0mm	22 (30.5%)
1.0mm	/E/	1.5mm	9 (12.5%)
1.5mm	/E/	2.0mm	3 (4%)
	E	2.0mm	7 (10%)

In 73.5 per cent of cases examined, therefore, the error was 1 mm or less. (Fig. 8).

The time of flight (t) measured above is not the same as in the foetal case: the time of flight measured in the neonate was from the probe surface to the distal skull margin and the path measured is therefore longer by the thickness of one side of the scalp than in the foetal measurements, but this is taken into account by calculating two separate factors to be applied in converting

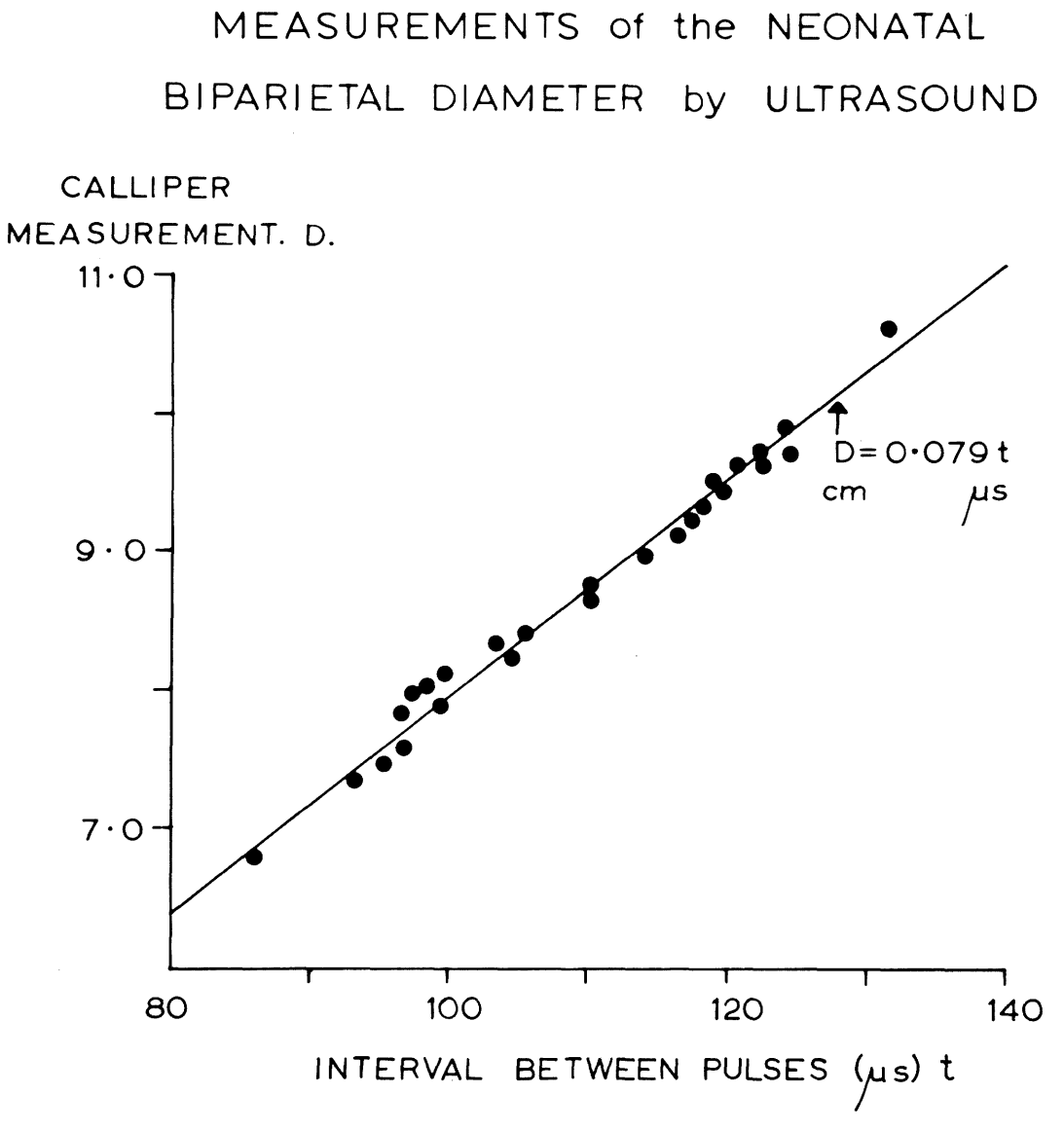


FIG. 8. This graph illustrates 26 of the 72 cases in which the biparietal diameter of normal neonates was measured by ultrasound and by calliper.

(ii) any foetal ultrasound measurement to the biparietal diameter.

These conversion factors are worked out in detail in the appendix to this section.

ESTIMATION OF THICKNESS OF SCALP AND SKULL IN THE MATURE FOETUS

The thicknesses of the skull and of the superficial tissues in the region of the parietal eminences were measured separately with a micrometer screw in a series of 18 post mortem specimens, all being normal infants weighing over 2000 grammes. The average thickness of the skull was 0.13 cm. and of the scalp 0.12 cm. (This measurement for the skull is more than that quoted by MACDONALD (1954) who, in a similar investigation found that the skull of the mature foetus was just under 0.1 cm. thick).

These data have permitted the velocities of ultrasound in the various components of the neonatal head to be resolved and the following results were obtained -

Velocity in soft tissues including brain = 1524 metres per second.

Velocity in skull (assumed to be 2 V soft) = 3048 metres per second.

Further details are given in the appendix.

APPLICATION TO FOETAL MEASUREMENTS

As has been mentioned above, a factor can be derived to convert the measurement of the time of flight of sound pulses in foetal investigations into an estimate of the biparietal diameter, but because the foetal measurement is

made from both skull margins the factor is slightly different.

Making the necessary assumptions, namely that both skull and scalp thickness are proportional to the biparietal diameter and that the post mortem data above are relevant and using the component velocities obtained above, the following factor is derived. (See Appendix)

$$d \text{ predicted} = 0.080 \text{ tf}.$$

Where d is the biparietal diameter in centimetres and tf the time obtained by ultrasonic examination of the biparietal diameter in the foetus.

APPENDIX

1. POST MORTEM SERIES

Measurements of skull and scalp thickness at the parietal eminences in stillborn infants or infants who died in the first week of life - all weighing over 2000 grammes and showing no gross abnormality. 18 cases examined.

Average skull thickness $\bar{d}_1$ (cm) = 0.13

Average scalp thickness $\bar{d}_2$ (cm) = 0.12

2. NEONATAL SERIES

Live infants in whom the biparietal diameter was estimated by ultrasound and calliper. 72 cases examined.

Average biparietal diameter by calliper $\bar{d}$ (cm) = 9.30

Average time of flight $\bar{t}$ (μs) = 117.8

The post mortem data are used to calculate component velocities.

$\bar{t}_1$, $\bar{t}_2$ are the time in skull and soft tissues.

$\bar{V}a$ is the average ultrasound velocity in skull.

$\bar{V}b$ is the average ultrasound velocity in soft tissues.

$$\bar{t} = \bar{t}_1 + \bar{t}_2$$

$$\bar{t} = \frac{2}{\bar{V}b} (\bar{d} - 2\,\bar{d}_1 - \bar{d}_2)$$

$$\bar{t}_2 = \frac{2}{\bar{V}a} (\bar{d}_1)$$

Assume $\bar{V}a = 2\,\bar{V}b$

$\bar{d}_1 = 0.13$ cm.

$\bar{d}_2 = 0.12$ cm.

Whence $\bar{V}a = 3048$ M/S

$\bar{V}b = 1524$ M/S

Application to Foetal Measurements -

Biparietal Diameter $d = Ktf$ where tf is the time between the foetal skull margine facing the probe spaced a distance df and where K is a constant.

$df = \bar{V}f \cdot tf/2$

$\bar{V}f$ can be calculated from average head data above.

$\bar{df} = (\bar{d} - \bar{d}_1 - 2\bar{d}_2)$

$\bar{V}f = \dfrac{2\,\bar{df}}{\bar{t}_1 + \bar{t}_2}$ $\bar{t}_1$ = time in skull in average head. $\bar{t}_2$ = time in soft tissue in average head.

and $\bar{t}_1 = \dfrac{2\,\bar{d}_1}{\bar{V}a}$

$\bar{t}_2 = \dfrac{2(\bar{d} - 2\bar{d}_1 - 2\bar{d}_2)}{\bar{V}b}$

and as above $\bar{d} = 9.30$ cm.

$\bar{d}_1 = 0.13$ cm.

$\bar{d}_2 = 0.12$ cm.

$\bar{V}b = 1524$ M/S

$\bar{V}a = 3048$ M/S

whence $Vf = \dfrac{2\,(\bar{d} - \bar{d}_1 - 2\bar{d}_2)}{\dfrac{2\bar{d}_1}{Va} + \dfrac{2(\bar{d} - 2\bar{d}_1 - 2\bar{d}_2)}{\bar{V}b}}$

$$= 1536 \text{ M/S}$$

$$\text{now } df = \bar{V}f \cdot tf/2$$

$$\text{but } d = df + d_1 + 2d_2$$

$$= df + k_1 d + 2K_2 d$$

$$\text{where } K_1 = \frac{d_1}{d} = \frac{\bar{d}_1}{d}$$

$$K_2 = \frac{d_2}{d} = \frac{\bar{d}_2}{\bar{d}}$$

$$\text{and } d = tf/2 \; \frac{\bar{V}f}{(1 - K_1 - 2K_2)}$$

$$= tf/2 \; \frac{\bar{V}f}{0.96}$$

$$d = tf \times 0.080$$

$K = 0.080$ d in cm., t in μs.

RESULTS

As has been shown above, an estimate of the neonatal biparietal diameter by ultrasound compared with a measurement made by calliper at the same time gave an error of 1 millimetre or less in 53 out of 72 cases, i.e. in abour 75 per cent of all cases.

The information obtained in neonates has been used to estimate the biparietal diameter of the foetal head by ultrasound. The biparietal diameter predicted from the ultrasound measurement is in good agreement with external measurements taken by calliper immediately after birth, as shown in figure 9 . In the cases illustrated, the external measurements were continued for at least 24 hours of life and all show a decrease in the biparietal diameter of between 4 and 6 millimetres in this time. This decrease in the biparietal diameter usually ceases after about 24 hours. The results of a series of daily measurements of the biparietal diameter of 38 neonates during the second to sixth days of life showed that in 23 cases the biparietal diameter varied by 1 millimetre or less during this time, and in a further 4 cases the variation was less than 2 millimetres. Of the remaining 11 cases, 3 showed steady growth in the biparietal diameter of about 3 millimetres in 5 days and 4 showed a decrease of 2.5 millimetres in 5 days.

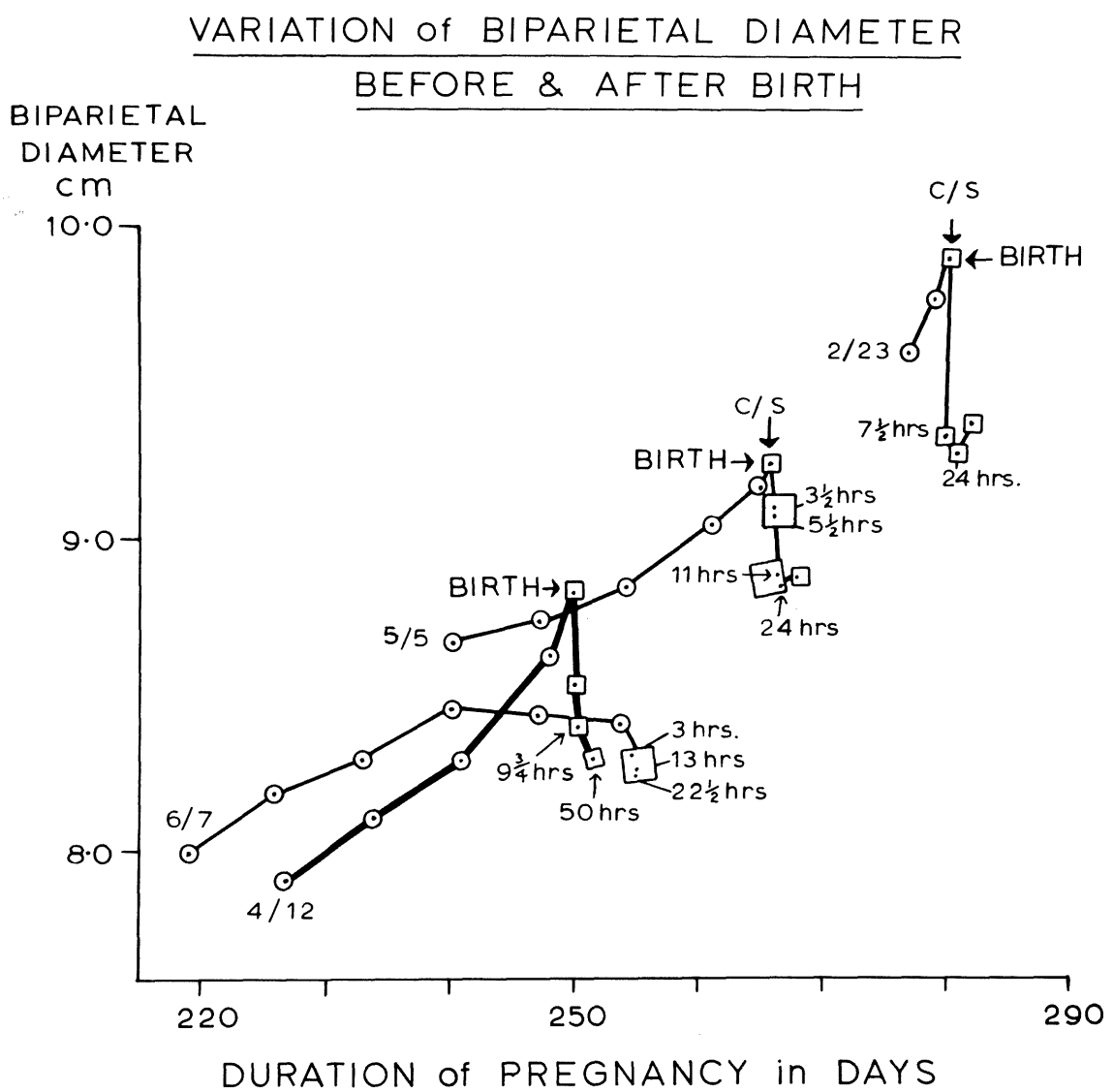


FIG. 9. Serial measurements of the biparietal diameter made before and after birth in 4 cases, illustrating the decrease in the biparietal diameter which is often observed in the first 24 hours after birth.

The table below compares the difference between the last foetal ultrasound measurement and a calliper measurement of the biparietal diameter taken between the first and fifth day of life - i.e. when the neonatal biparietal diameter is less likely to be changing. The cases have been limited to those in which the foetal measurement was taken during the five days before birth.

DIFFERENCE BETWEEN LAST FOETAL ESTIMATE OF BIPARIETAL DIAMETER AND EXTERNAL CALLIPER MEASUREMENT

	-1mm to 1mm	1mm to 3mm	3mm to 5mm	5mm to 7mm	7mm to 9mm	9mm to 11mm
Caesarean Sections-22	3	6	8	4	1	0
Other Deliveries-31 (22 SVD)	2	4	6	10	7	2

The biparietal diameter has decreased in the majority of these cases between the time of the foetal estimate and that of external measurement by calliper. The work on neonates described above suggests that most of this decrease occurs during the first few hours of life. Of the 53 cases listed, 22 deliveries by Caesarean section showed an average decrease of 3.4 millimetres and the 31 vaginal deliveries showed an average decrease of 5.3 millimetres in the biparietal diameter.

Foetal estimates of the biparietal diameter cannot therefore be compared directly with calliper measurements after birth unless these are taken at or immediately after birth. The reasons for this observed alteration of the

biparietal diameter during the first day of life are obscure. It had been expected that the heads of infants delivered vaginally would increase in size as moulding passed off and that those delivered by Caesarean section while the head was still above the pelvic brim would be unchanged. The observed decrease might be attributed to the effects of nursing with the baby lying on its side.

Ultrasonic estimates of the biparietal diameter of the foetal head have been made in more than 400 patients in the Glasgow Royal Maternity Hospital. Often these have been repeated at weekly intervals during the last 10 weeks of pregnancy. The results in all cases are not quoted in detail in the pages which follow, because of the absence of a real clinical application in some of them, especially during the time that the method was being developed.

In general terms, the objects of the study have been threefold.

(1) To determine presentation in doubtful cases.

(2) To assess foetal size.

(3) To follow foetal growth.

Presentation can be determined in doubtful cases without taking an x-ray if the characteristic echoes from the foetal head are clearly seen. The assessment of foetal size by cephalometry is valuable in cases of disproportion where the size of the head itself is of the greatest importance, but the biparietal diameter is also

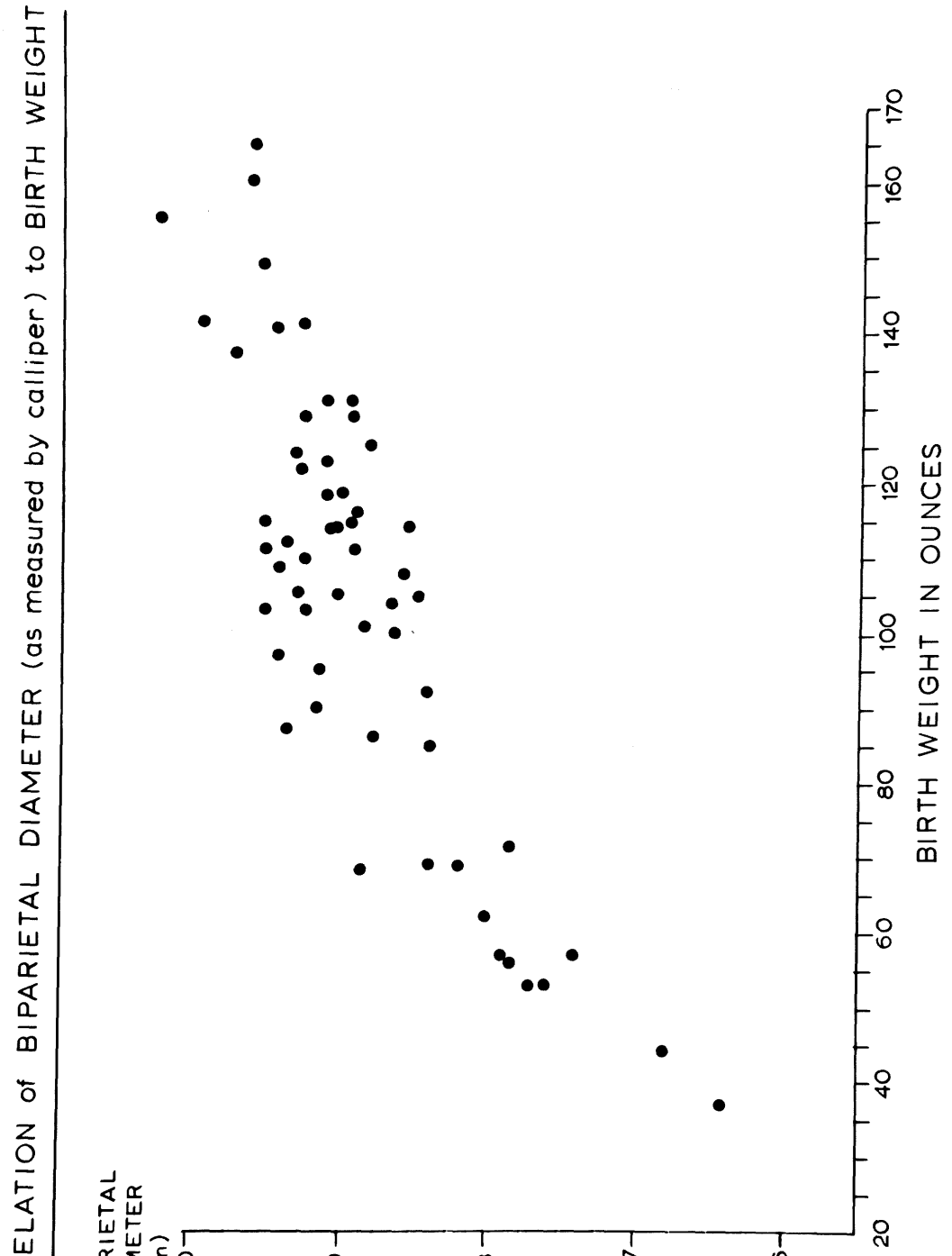


FIG. 10. Biparietal diameter in relation to birth weight.

related to weight as is shown in figure 10 and thus can give a guide to the overall size of the baby.

Assessment of foetal growth is a complex problem, because of the many variables involved. POTTER (1957) writes, "Growth before birth proceeds at a variable rate, the same as it does after birth. This is particularly well illustrated by the variation in the weights of twins. In pregnancies in which at least one twin weighs more than 2500 grammes, the average difference in weights of the twins is 500 grammes. Length of the foetus is generally proportional to weight, although in the malformed foetus some disparity often exists. Most of the subcutaneous adipose tissue is deposited in the last weeks of pregnancy and at this time increase in weight is greater in relation to length than at any other period of gestation".

SCAMMON and CALKINS (1929) gave, from postmortem examinations, the following figures for the growth of the biparietal diameter in utero.

GROWTH OF FOETAL BIPARIETAL DIAMETER
(After Scammon & Calkins)

Duration of Pregnancy in Weeks	Biparietal Diameter in Centimetres
12	1.55
16	3.15
20	4.53
24	5.75
28	6.86
32	7.88
36	8.84
40	9.74

It must be remembered that as these figures are based on dead infants they are likely to be somewhat smaller than in life.

It was hoped that repeated ultrasonic measurements of the biparietal diameter would give useful information about foetal growth in normal and abnormal pregnancy and the clinical applications are discussed in more detail in the illustrative cases which follow.
Changes in the foetal biparietal diameter as measured by ultrasound usually appear to be linear in time, but in some instances, as will be seen in the illustrative cases, an alteration in the growth rate or even a progressive decrease may sometimes occur and this may be of considerable clinical significance.

In a series of 39 cases which were studied between the 210th and 280th day of pregnancy the average growth rate of the biparietal diameter was 0.252 mm. a day, i.e.

1.76 mm. a week. The comparable figures derived from the work of SCAMMON and CALKINS mentioned above are 0.332 mm. a day, or 2.325 mm. a week.

As it is felt that the information obtained in individual cases was of more practical clinical value than any conclusion drawn from the results as a whole, the following series of 125 illustrative cases is presented, divided into groups according to the medical condition of the patients. The author knew all these patients well - some of them in several pregnancies - and played an active part in their obstetrical management.

The following groups have been defined -

1. Normal Pregnancy
2. Prolonged Pregnancy
3. Contracted Pelvis
4. Cardiac Disease
5. Anaemia
6. Antepartum Haemorrhage
7. Hypertension and Pre-eclampsia
8. Placental Insufficiency
9. Diabetes
10. Malpresentation and Variable Lie of the Foetus
11. Multiple Pregnancy
12. Foetal Abnormality.

The cases have been arranged according to the number of measurements taken, those in whom most measurements were made being placed first in each group.

Graphs illustrating the growth of the biparietal diameter are included where indicated, and a key to the symbols used in the graphs is given on the following page.

SYMBOLS USED IN GRAPHS

⊙ Foetal biparietal diameter estimated by ultrasound.

⊡ External calliper measurement after birth.

y Biparietal diameter in centimetres.

t Duration of pregnancy in days.

GROUP I

NORMAL PREGNANCY

The conditions under which this work was done made it impossible to assemble a large series of normal cases who would, of course, be out-patients. Even if it had been possible to study out-patients more extensively, the high incidence of obstetrical abnormality in women attending the antenatal clinic at the Glasgow Royal Maternity Hospital would still have made it difficult. The patients reviewed here must merely be studied as illustrative cases: no attempt can be made to draw general conclusions from this small group.

Some of these patients were admitted to hospital antenatally for reasons likely to be unconnected with foetal growth - e.g. previous Caesarean section for a non-recurrent indication.

CASE NO. 1

Mrs. Annie Thomson, aged 29 years, attended the hospital during her fifth pregnancy. She had no living children: her first 2 pregnancies ended in miscarriage at 20 and 24 weeks and in her third and fourth pregnancies she was delivered at 30 weeks of premature infants weighing 3 and $3\frac{1}{2}$ pounds who died in the neonatal period.

Early in the fifth pregnancy she was noted to have an incompetent cervix, probably the cause of her previous obstetrical misfortunes. This was treated by Shirodkar's operation at 16 weeks and thereafter the pregnancy progressed normally. Labour commenced 10 days before the expected date, and, after $2\frac{1}{2}$ hours, she had a spontaneous vertex delivery of a live male child weighing 7 pounds 3 ounces.

INDICATION FOR CEPHALOMETRY

To observe foetal growth in a case where a careful estimate of size at frequent intervals was valuable in view of the failure of previous pregnancies to reach maturity.

RESULT

Despite the previous history, pregnancy progressed normally and an interesting series of 9 measurements of the biparietal diameter was obtained at weekly intervals from the 30th to the 38th week of pregnancy. This indicated steady growth of the foetus throughout (Fig. 11).

FIG. 11 Annie THOMSON

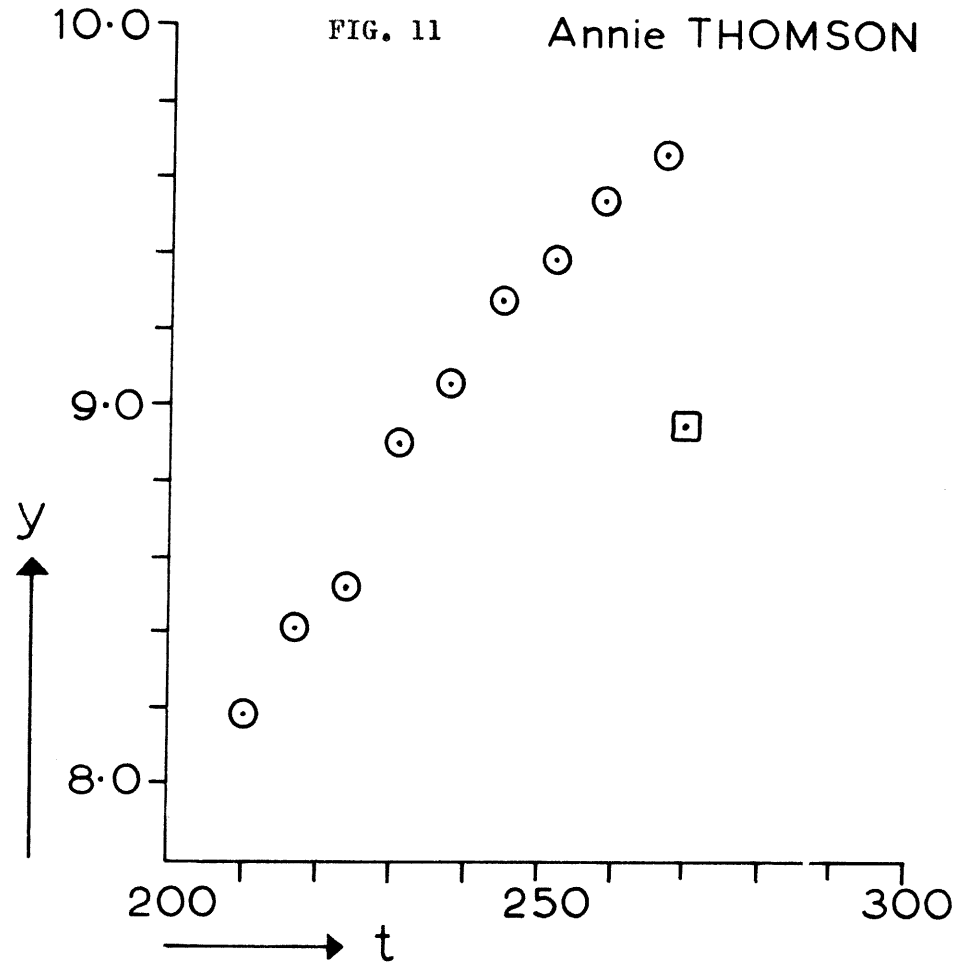
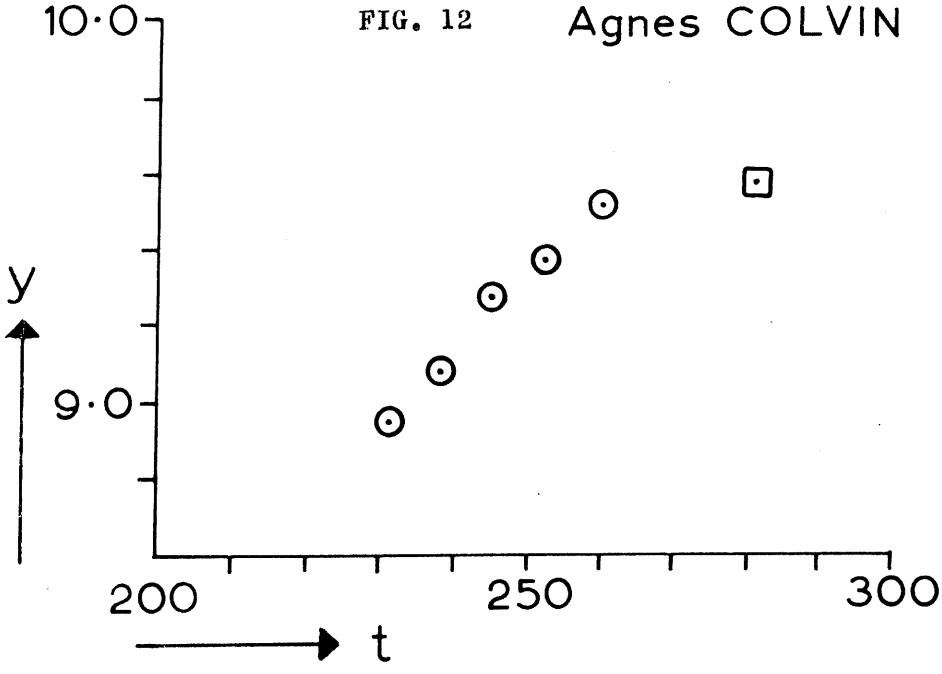


FIG. 12 Agnes COLVIN



FIGURES 11 and 12 illustrate the growth of the biparietal diameter in normal pregnancy.

CASE NO. 2

Mrs. Agnes Colvin, aged 26 years, had one previous pregnancy and labour ending in the birth of a 9 pound baby. No significant complications arose during her second pregnancy and at term she had a normal labour and spontaneous delivery of a boy weighing 10 pounds 5 ounces.

INDICATION FOR CEPHALOMETRY

To observe normal foetal growth.

RESULT

Five weekly measurements were made from the 33rd to the 38th week, indicating steady growth. The patient did not attend again until she was admitted in labour. (Fig. 12).

CASE NO. 3

Mrs. Georgina Rennie, aged 31 years, had three babies all of whom weighed about 9 pounds at birth. She progressed normally during her fourth pregnancy and at term had a spontaneous vertex delivery of a boy weighing 8 pounds 9 ounces.

INDICATION FOR CEPHALOMETRY

To observe normal foetal growth.

RESULT

Five measurements were made between the 33rd and 38th week, indicating steady growth. (Fig. 13).

CASE NO. 4

Mrs. Elsie Love, aged 37 years, had 3 previous pregnancies, two ending in the normal delivery of 7 pound babies, and one in a 3 month miscarriage. She was well during her fourth pregnancy and the day after her expected date she had a normal labour and spontaneous delivery of a boy weighing 8 pounds 7 ounces.

INDICATION FOR CEPHALOMETRY

To observe foetal growth.

RESULT

Three measurements were obtained between the 34th and 38th weeks of pregnancy, indicating steady growth. (Fig. 14).

CASE NO. 5

Miss Catherine Campbell, aged 27 years, had one previous pregnancy: the delivery was normal and the baby weighed $8\frac{1}{2}$ pounds. She was well during her second pregnancy until the 30th week, when the membranes ruptured for no apparent reason. Labour did not commence until 3 weeks later and ended in the spontaneous delivery of a live male child weighing $5\frac{1}{2}$ pounds.

INDICATION FOR CEPHALOMETRY

To assess foetal size in a case where premature labour appeared imminent as the membranes had already ruptured.

FIG. 13

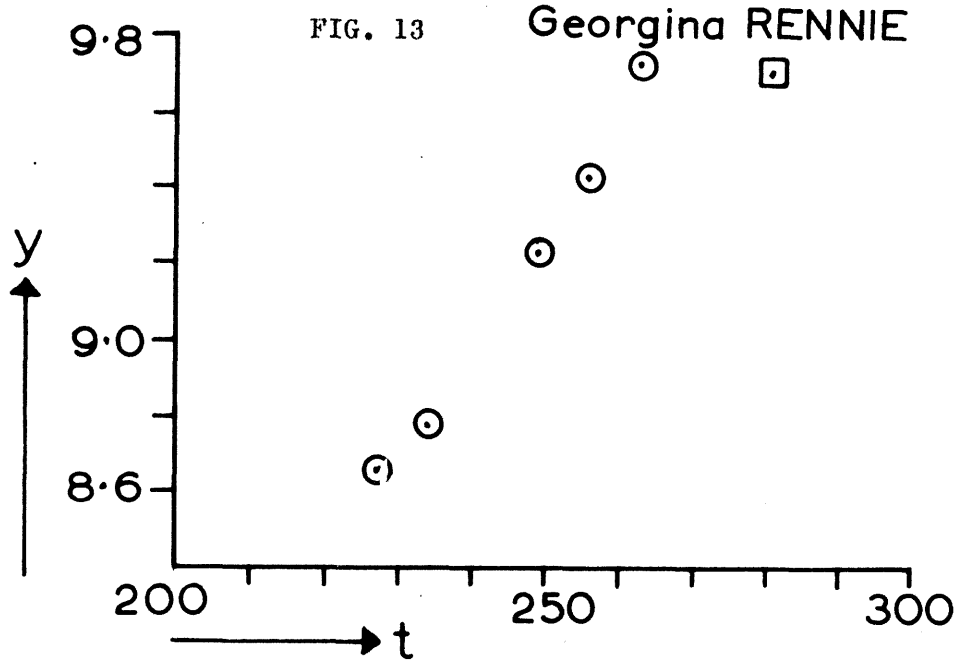


FIG. 14

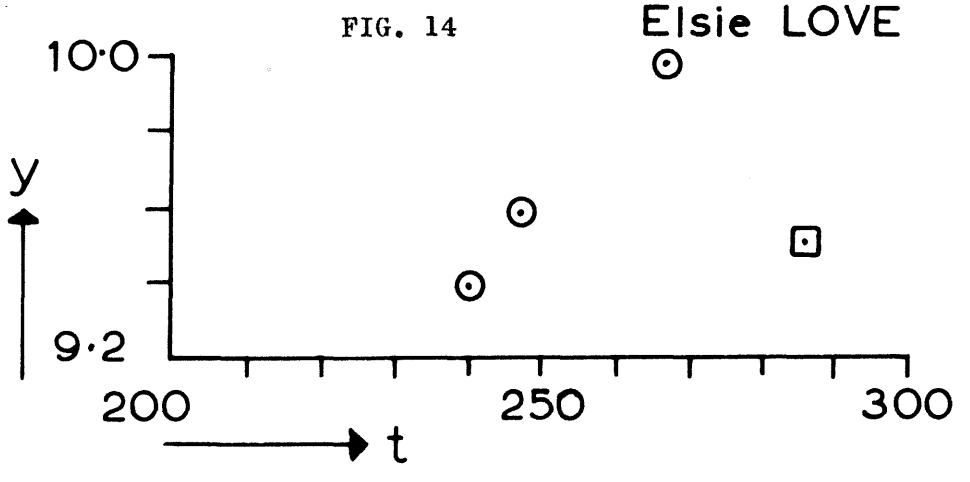
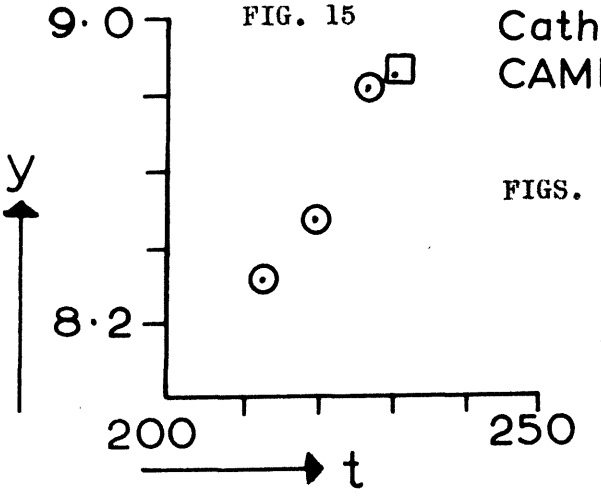


FIG. 15



FIGS. 13, 14 & 15, Growth of biparietal diameter in normal pregnancy. Labour was premature in the case illustrated in FIG. 15.

RESULT

As labour did not, in fact, begin until 3 weeks later, 3 measurements were obtained: these indicated a progressive increase in the biparietal diameter. (Fig. 15).

CASE NO. 6

Mrs. Patricia Smith, a primigravida aged 25 years, was well during pregnancy. Labour began 2 days past the expected date and was prolonged and inco-ordinate, lasting 74 hours. She was delivered by Vacuum extraction of a live male child weighing 8 pounds 3 ounces.

INDICATION FOR CEPHALOMETRY

To assess foetal size at term.

RESULT

Two measurements were obtained in the last week of pregnancy: they differed by only a fraction of a millimetre.

Date	B.P.D.	
26:4:62	9.49 cm.)	by ultrasound
30:4:62	9.46 cm.)	

The calliper measurement 24 hours after birth was 8.93 cm., showing the normal decrease.

CASE NO. 7

Mrs. Mary Bell, aged 33 years, had had 4 previous pregnancies: the babies weighed between 7 and 9 pounds at birth. She was well during this pregnancy apart from mild iron-deficiency anaemia. Eleven days before her expected date she had a normal labour and spontaneous delivery of a live female child weighing 7 pounds 13 ounces.

INDICATION FOR CEPHALOMETRY

To assess foetal size.

RESULT

Two measurements were obtained in the 38th week of pregnancy, an interval of 3 days intervening. They did not differ, both being 8.9 cm. The calliper measurement on the second day of life was 8.8 cm.

CASE NO. 8

Mrs. Irene Gardner had only one living child from 5 previous pregnancies. She had had 2 miscarriages at 12 weeks and 2 stillbirths, both due to concealed accidental haemorrhage at term. Her last pregnancy was terminated by Caesarean section at 38 weeks and the child did well.

On the present occasion she was well throughout pregnancy. She was delivered by elective Caesarean section 2 days before her expected date. The baby, a boy, weighed $7\frac{1}{2}$ pounds.

INDICATION FOR CEPHALOMETRY

To confirm foetal growth in the last month of pregnancy.

RESULT

Two measurements were obtained, one in the 36th week and the other in the 38th week. They showed an increase in the biparietal diameter of 0.4 cm., being 9.2 and 9.6 cm. respectively. A calliper measurement on the 7th day of life showed the usual decrease, being 9.1 cm.

CASE NO. 9

Mrs. Frances Cameron, aged 36 years, was delivered in her only previous pregnancy by Caesarean section because of prolonged labour; the baby weighed 9 pounds 7 ounces. At term in her second pregnancy, the biparietal was 9.90 cm. by ultrasound. Six days later, following surgical induction, she had a 7 pound 12 ounce female child delivered by Vacuum extraction. On the 4th day of life, the biparietal, measured by calliper, was 9.93 cm.

CASE NO. 10

Mrs. Joan Marsh, aged 35 years, had one child who weighed 3 pounds 14 ounces at birth. The delivery was by Caesarean section at 38 weeks because of pre-eclampsia. In her second pregnancy, which progressed normally, labour

was induced 5 days past her expected date and she had a Vacuum extraction of a live female child weighing 6 pounds 12 ounces.

INDICATION FOR CEPHALOMETRY

Previous placental insufficiency.

RESULT

At term, the biparietal diameter measured 9.32 cm. by ultrasound. Seven days later (24 hours after birth) the calliper measurement was 9.61 cm.

CASE NO. 11

Mrs. Irene Morgan, aged 33 years, had had 2 previous spontaneous deliveries of babies weighing 8 pounds. On the last occasion uterine rupture had occurred at delivery and a large retrovesical haematoma was evacuated by laparotomy. Her third pregnancy progressed normally, but it was decided to deliver her by elective Caesarean section because of her history. This was done 12 days before her expected date. The child, a girl, weighed 8 pounds 13 ounces. Ultrasonic cephalometry 3 days before delivery estimated the biparietal as 9.72 cm. The calliper measurement 24 hours after birth was 9.66 cm.

CASE NO. 12

Mrs. Mary Wilson, a primigravida aged 33 years, had a normal pregnancy. The foetal biparietal diameter measured 9.5 cm. by ultrasound at term. She had a

spontaneous delivery of a boy weighing 6 pounds 10 ounces 2 days later. The biparietal measured 9.25 cm. by calliper 24 hours after birth.

GROUP 2

PROLONGED PREGNANCY

The opportunity of observing alterations in the foetal biparietal diameter beyond the 40th week of pregnancy has been very limited, as it is the practice of the Unit to induce labour at 42 weeks on the ground of postmaturity. Uncomplicated cases admitted for this purpose are likely to spend about 24 hours in the antenatal ward before induction is undertaken so that it is not possible to obtain serial measurements.

The patients included in this group are those in whom the only significant feature was prolonged gestation. Prolonged pregnancy was an incidental feature of some cases included in other groups.

The growth of the foetus after term has been a subject of debate among obstetricians. CALKINS (1948) was of the opinion that most foetal growth takes place before the 260th day of pregnancy and MILLS (1953) suggested that foetal growth ceases after term and that the foetus may sometimes even lose weight in utero - a view also supported by McCANCE (1962). McKEOWN and GIBSON (1951) reported that in a large series of cases the birth weight increased only very slightly after the 40th week.

However, evidence has been provided by MACDONALD (1953, 1954) and CRICHTON (1953) in their work, which has already been described, to suggest that the foetal

head continues to grow in utero after term. BROWNE (1962) thinks that the hazard of prolonged pregnancy may arise in two ways. Firstly, if the placenta is a good one with ample reserves the baby continues to grow during the extra week or two of pregnancy and disproportion may ensue, often associated, too, with uterine dysfunction. Secondly, there appears to be a limit to the useful life of the placenta, and when this is reached the baby at first ceases to grow, then suffers increasingly from placental insufficiency, and finally dies from anoxia. In any discussion about prolonged pregnancy it is most important that the patient's expected date be assessed from the menstrual history, the findings on examination in early pregnancy and other relevant evidence, with as much accuracy as possible. Every attempt is made to do this in the patients attending the hospital.

The cases reviewed here do not provide any general information about the growth of the foetus after term, but are of some interest in themselves. Further work would require to be undertaken in a Unit where no clinical significance is attached to prolonged pregnancy before any conclusions could be made.

However, it is to be hoped that ultrasonic cephalometry will prove useful in these cases, as the detection of undue size of the infant or of cessation of foetal growth are both of great importance.

CASE NO. 1

Mrs. Elizabeth Kelly, aged 19 years, was in her second pregnancy. She had a history of epilepsy but had no fits during this pregnancy. Her last child had been delivered by Caesarean section on account of frequent fits: that child's birth weight was $9\frac{3}{4}$ pounds. Her second pregnancy continued until 17 days past the expected date when labour was induced surgically: 14 hours later she had a spontaneous vertex delivery of a live female child weighing 8 pounds.

INDICATION FOR CEPHALOMETRY

To observe foetal growth in the last month of pregnancy.

RESULT

Seven measurements of the biparietal diameter were obtained between the 37th and 43rd week of pregnancy. These showed no evidence of significant increase after term. (Fig. 16).

CASE NO. 2

Mrs. Agnes Forrester, a primigravida aged 34 years, was on maintenance steroid therapy for polyarthritis but was otherwise well during pregnancy. She was delivered 10 days past her expected date of a boy weighing 10 pounds.

INDICATION FOR CEPHALOMETRY

To assess foetal size, as this seemed a big baby.

FIG. 16 Elizabeth KELLY

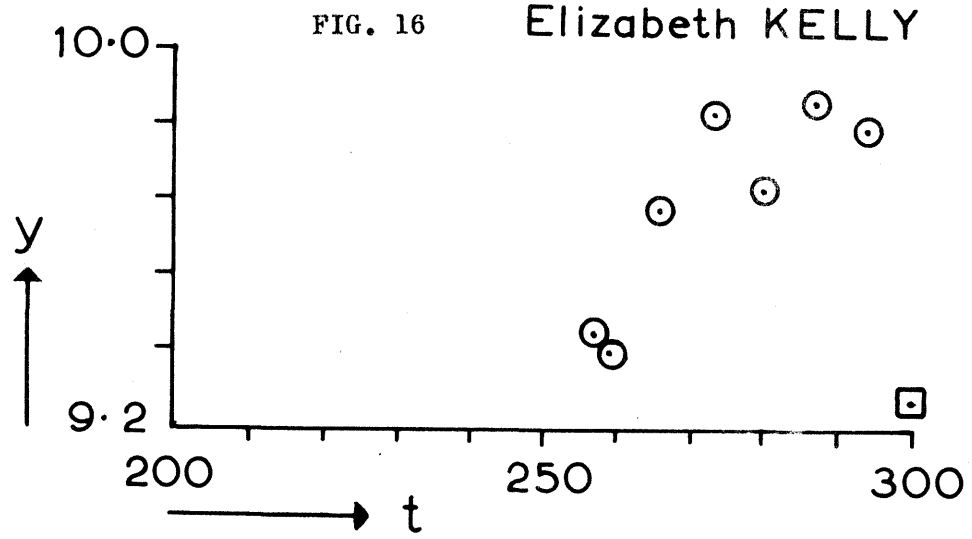
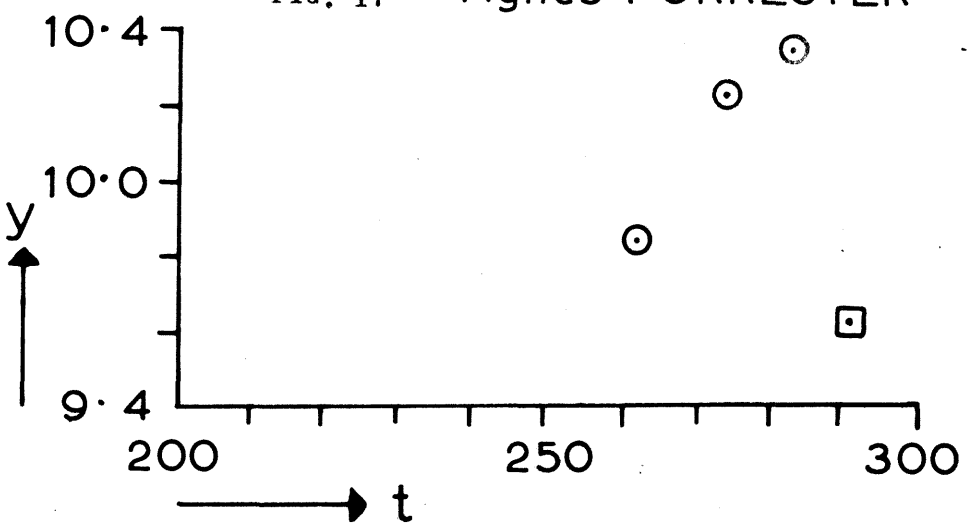


FIG. 17 Agnes FORRESTER



FIGS. 16 & 17. Estimates of the foetal biparietal diameter in prolonged pregnancy. The pattern in FIG. 16 suggests that there was probably no foetal growth after term.

RESULT

Three measurements were made antenatally, confirming that the foetus was large. Between the 37th and 39th week the biparietal diameter appeared to increase by 4 millimetres. In the subsequent 10 days it increased by only a millimetre. (Fig. 17).

CASE NO. 3

Mrs. Catherine MacLellan, aged 35 years, had 9 previous full-time pregnancies, the birth weights of the babies being between 6 and 8 pounds. She was admitted at term because of a history of rheumatic heart disease. Labour was induced 14 days past the expected date and she had a normal delivery of a live male child weighing 7 pounds 2 ounces.

INDICATION FOR CEPHALOMETRY

To assess foetal size.

RESULT

Two measurements were made, on the 285th and 289th days: they showed no significant difference, both being 8.9 cm. The calliper measurement 6 days after birth was 9.03 cm.

GROUP 3

CONTRACTED PELVIS

The question of the value of foetal cephalometry in cases of contracted pelvis has already been discussed at some length in the section on "The Place of Foetal Cephalometry in Obstetrics".

CRICHTON (1962) in his William Blair Bell Memorial Lecture on "The Accuracy and Value of Cephalo-pelvimetry" reviewed the work of 9 years, first at Oxford, then at Durban, during which he dealt with more than 3,000 cases in whom cephalo-pelvimetry was performed.

He once more stressed the value of the biparietal diameter as the most important measurement of the foetal head and, in particular, he showed that the obstetric significance of the biparietal diameter is superior to that of the average cranial circumference - the method advocated by BALL (1935 and 1936). CRICHTON prefers intrapartum to antenatal cephalo-pelvimetry because in labour the head is usually fixed. "Unfortunately", he says, "the biparietal diameter of any high head - which one associates with brim disproportion - has a tendency to present unfavourably in this (i.e. the lateral) radiograph. Thus only 33 per cent of unmoulded biparietal diameters presented, or could be deduced fairly accurately from antenatal radiography in the present series".

This is a most important statement, based as it is on such extensive experience, and it shows what severe limitations the radiological method has. By contrast, it is very rarely that one is unable to make a measurement by the ultrasonic method.

The information obtainable by cephalometry is wanted before the start of a trial of labour, not during it, and the ultrasonic method can give this in practically every case. The accuracy of the method has already been discussed and is demonstrated in connection with cases in other clinical groups. What follows now is merely a small series of illustrative cases in which disproportion was the clinical problem and where x-ray pelvimetry had already been done.

No one should over-estimate the value of cephalo-pelvimetry in the management of disproportion. To quote CRICHTON (1962) again, "Having regard to the many variables in labour, we cannot expect precision forecasts about an outcome of labour from a method which provides measurement of only one - albeit important - faecet of the problem".

CASE NO. 1

Mrs. Phyllis Grant, a primigravida aged 20 years, was noted to have a minor degree of pelvic contraction on examination at the 36th week. X-ray pelvimetry was performed at 37 weeks and showed slight inlet contraction, the true conjugate being 9.9 cm. The radiological estimate of the biparietal diameter was approximately 9.1 cm. On ultrasonic examination the following day the biparietal diameter was estimated to be 9.3 cm.

The foetal head remained high and free until the onset of labour, which was spontaneous, 5 days after the expected date. After a labour lasting 39 hours there was a spontaneous vertex delivery of a live male child weighing 6 pounds 14 ounces.

INDICATION FOR CEPHALOMETRY

Suspected disproportion: High, free foetal head.

RESULT

After the measurement given above, 3 other antenatal measurements were made, the last just before labour started. A progressive increase in the biparietal diameter was demonstrated. Labour was not easy in this case and there was fairly marked moulding of the foetal head at birth. (Fig. 18).

CASE NO. 2

Mrs. Mary McLean, a primigravida aged 24 years, was

FIG. 18 Phyllis GRANT

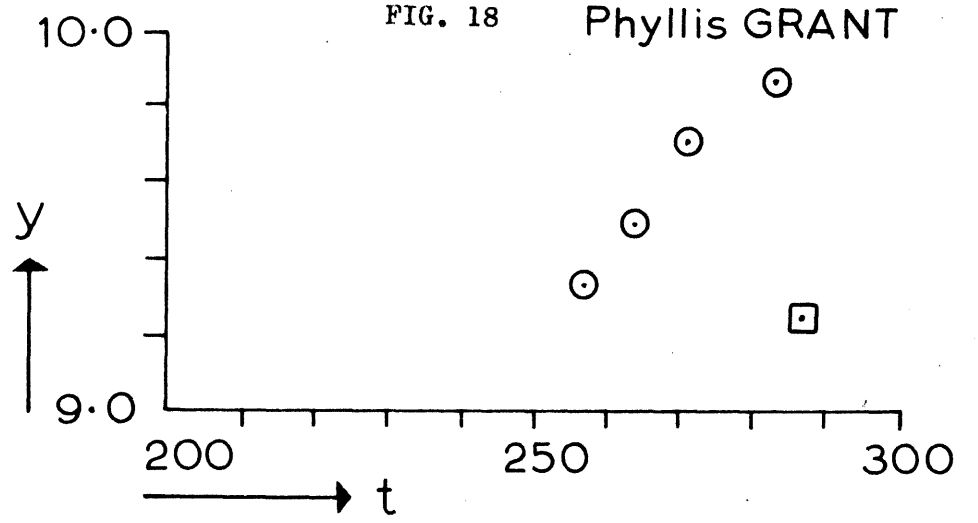
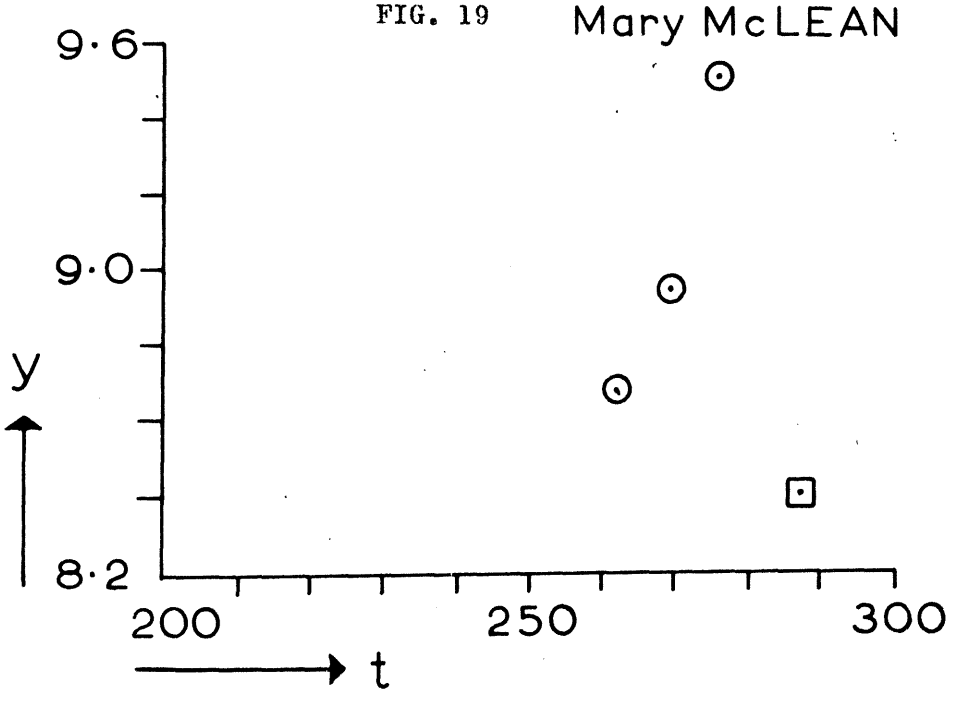


FIG. 19 Mary McLEAN



FIGS. 18 & 19. Growth of the biparietal diameter demonstrated in cases of borderline disproportion. Both were spontaneous vertex deliveries.

found to have a moderate degree of contraction at the inlet and mid pelvis. The true conjugate was 10.1 cm. by x-ray. The foetal head became engaged a few days before the onset of labour which was 4 days after term. The patient had a normal labour and spontaneous delivery of a live male child weighing 5 pounds 5 ounces.

INDICATION FOR CEPHALOMETRY

Contracted pelvis.

RESULT

Clinically, this seemed a small baby. Two of the three ultrasonic measurements made between the 37th week and term seemed to confirm this. With the last measurement, there was a surprising increase, probably an error, as the measurement made by calliper after birth was more in accord with the earlier readings. (Fig. 19).

CASE NO. 3

Mrs. Harriet McKay was a primigravida aged 40 years. X-ray pelvimetry confirmed marked funnelling of the pelvis towards the outlet, which showed significant contraction transversely. While the true conjugate was 11.9 cm., the interspinous diameter was 9.2 cm. and the intertuberous 8.5 cm. The foetal biparietal diameter could not be estimated radiologically. The patient was advised to have an elective Caesarean section but she, who was herself a midwife, did not want this. However,

after 10 hours in labour gross disproportion was evident and Caesarean section was performed. The child, a female, weighed 9 pounds 5 ounces.

INDICATION FOR CEPHALOMETRY

Contracted pelvis. Probable disproportion.

RESULT

The first reading, of 9.4 cm., was rather difficult to obtain and was not thought very reliable. The examination was repeated 4 days later - the day before labour started - and very clear echoes were obtained, giving a reading of 9.9 cm. This was not inconsistent with the measurement made on the baby on the 3rd day of life when the biparietal diameter was 9.5 cm.

CASE NO. 4

Miss Christine Docherty, aged 22 years, had poliomyelitis in childhood. As a result she had a deformity of both legs and walked only with the aid of callipers. This was her first pregnancy. The pelvis was asymmetrical and slightly contracted, the true conjugate being 9.9 cm. by x-ray. It was decided to deliver her by elective Caesarean section. This was done at 39 weeks. A live male child weighing 7 pounds 9 ounces was extracted.

INDICATION FOR CEPHALOMETRY

Contracted pelvis.

RESULT

Measurements made in the 38th and 39th weeks were 9.2 cm. and 9.1 cm. respectively. X-ray pelvimetry had been performed at the 30th week when the radiological estimate of the biparietal was 8.3 cm. Unfortunately, no postnatal measurement was made in this case but the baby's weight was compatible with the measurements made by ultrasound.

CASE NO. 5

Mrs. McKechnie, a primigravida, had suffered from rickets in childhood and had a flat contracted pelvis, the true conjugate being 7.8 cm. by x-ray. She was delivered by elective Caesarean section at 39 weeks of a live male child weighing 6 pounds 13 ounces.

INDICATION FOR CEPHALOMETRY

Contracted pelvis.

RESULT

Two measurements, at the 38th and 39th weeks, were both 8.7 cm. The calliper measurement on the day after birth was 8.6 cm. Cephalometry in this case was only an academic exercise as there was gross clinical disproportion and elective Caesarean section was the only reasonable treatment.

CASE NO. 6

Mrs. McKenzie had had 2 previous Caesarean sections

on account of contracted pelvis. The true conjugate was 9.0 cm. Her third pregnancy was also terminated by Caesarean section.

RESULT

Here also there was no clinical value in cephalometry as the two previous sections were sufficient indication for the operation to be repeated. A measurement of 8.8 cm. made 3 days before birth contrasted with a calliper measurement of 8.5 cm. 24 hours after birth.

CASE NO. 7

Mrs. McGlinchy had also had 2 previous Caesarean sections for contracted pelvis and was delivered in the same manner in her third pregnancy.

RESULT

The foetal biparietal diameter was measured a few hours before delivery: it was 10.1 cm. A calliper measurement 3 days later was 9.5 cm. Again, cephalometry had no clinical value here.

CASE NO. 8

Mrs. Cowan, a primigravida aged 35 years, was found to have a generally contracted pelvis, the true conjugate being 9.3 cm. Labour did not commence at term and 8 days later she was delivered by Caesarean section of a boy weighing 5 pounds 13 ounces.

INDICATION FOR CEPHALOMETRY

Suspected disproportion. Contracted pelvis.

RESULT

The foetal head was measured at 39 weeks when the biparietal was estimated at 8.4 cm. On the day of delivery (i.e. 14 days later) the calliper measurement was 8.0 cm. The baby in this case was not large, but other factors including maternal age weighed the balance in favour of abdominal delivery.

CASE NO. 9

Mrs. Murray had had a stillbirth from her only previous pregnancy. She had a moderate degree of pelvic contraction, the true conjugate being 9.6 cm. by x-ray. Labour commenced spontaneously at term and progressed rapidly. Full dilatation of the cervix was reached in 6 hours but the head remained above the pelvic brim. She was, therefore, delivered by Caesarean section.

INDICATION FOR CEPHALOMETRY

Suspected disproportion.

RESULT

The outcome in this case could have almost been foretold from the measurement made at term (before the start of labour) which was 10.3 cm. The calliper measurement 3 days after birth was 9.6 cm.

CASE NO. 10

Mrs. Margaret Coutts, a primigravida aged 22 years, had a minor degree of pelvic contraction, the true conjugate being 10.1 cm. and the sacrum flat. She was admitted to hospital at 42 weeks. Ultrasonic cephalometry gave an estimate of the biparietal at 9.9 cm. Labour was induced and after 24 hours forceps delivery was performed because of foetal distress. The child was stillborn, (the cord being twice round the neck) and weighed 6 pounds 14 ounces. A calliper measurement of the biparietal was 9.2 cm.

CASE NO. 11

Mrs. Helen Murphy, a primigravida aged 31 years, was found to have a contracted pelvis with funnelling towards the outlet. X-ray pelvimetry at 36 weeks gave the measurement of the true conjugate as 9.8 cm. and the biparietal as 8.7 cm. Nearly 4 weeks later (one day before term) the ultrasonic measurement of the biparietal was 9.3 cm. The patient was delivered by elective Caesarean section on her expected date as it was thought inadvisable to allow labour in a case where the outlet was so markedly reduced. The child, a girl weighed $6\frac{1}{2}$ pounds. The calliper measurement of the biparietal next day was 8.6 cm.

CASE NO 12

Mrs. Agnes Noble, a primigravida aged 41 years, was noted clinically to have a reduced pelvic outlet and a flat sacrum. X-ray pelvimetry showed a large platypelloid pelvis with a flat sacrum, there being plenty of room at the inlet but moderate contraction in mid pelvis. The x-ray estimate of the biparietal (at 36 weeks) was 8.3 cm. At term, the ultrasonic estimate of the biparietal was 9.3 cm. Following induction at term the patient had an 8 hour labour terminating in an easy forceps delivery of a live male child weighing 7 pounds 4 ounces. Calliper measurement of the biparietal 2 days later was 8.6 cm.

In this case it was only because the baby was not large and the pelvic contraction was slight that the patient was allowed to go into labour at all, in view of her age and parity. The treatment was well justified by the good result.

CASE NO. 13

Mrs. Catherine Harper, aged 25 years, had one previous pregnancy when she was delivered of a 6 pound 12 ounce baby by Caesarean section because of disproportion. In her second pregnancy, she was admitted to hospital 2 days before her expected date. Disproportion was again suspected. Ultrasonic measurement of the biparietal diameter on admission was

9.5 cm. X-ray the following day gave exactly the same measurement of the biparietal and also showed a justo-minor pelvis with definite disproportion, the true conjugate being 9.1 cm. Three days later elective Caesarean section was performed and a live female child weighing 5 pounds 14 ounces was extracted. The biparietal was measured by ultrasound and calliper 3 hours after birth. The ultrasonic measurement was 9.40 cm. and the calliper measurement 9.44 cm.; 3 days later the measurements were 9.05 cm. and 9.16 cm. respectively.

This was an interesting case in that an x-ray measurement before birth coincided exactly with the ultrasonic measurement and that a postnatal decrease in the biparietal diameter was demonstrated. (Fig. 20).

CASE NO. 14

Mrs. Elizabeth Main, aged 24 years, had an asymmetrical pelvis and an arthrodesis of the right hip as the result of a road accident. Her one previous child (birth weight 6 pounds 10 ounces) had been delivered by Caesarean section after a short trial of labour. Near term in her second pregnancy it was decided that there was no disproportion despite the pelvic asymmetry and that she should be allowed to go into labour again. Ultrasonic measurement of the biparietal 5 days before term was 9.48 cm. Three days

FIG. 20

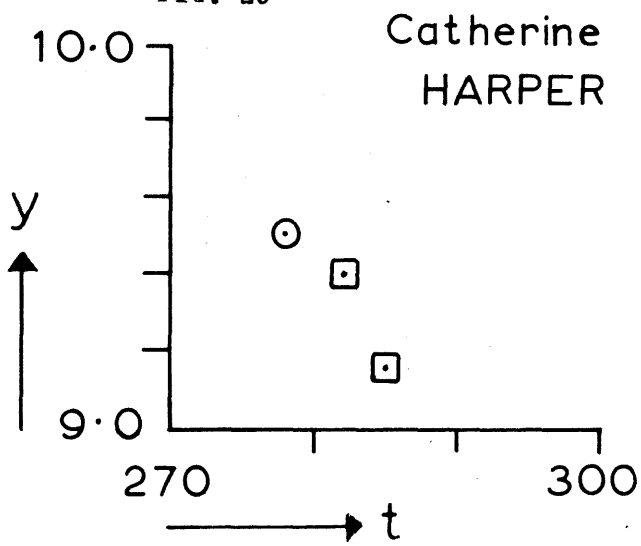


FIG. 20. Cephalopelvic disproportion.
The biparietal diameter was estimated by ultrasound as 9.5 cm. An x-ray measurement made at the same time exactly coincided with this. The true conjugate diameter of the pelvis measured 9.1 cm. by x-ray.
Delivery by elective Caesarean section.
Note decrease in the biparietal diameter after birth.

later the patient had a normal labour and a spontaneous delivery of a live female child weighing 6 pounds 10 ounces. The calliper measurement on the following day was 9.35 cm.

CASE NO. 15

Mrs. Rose Forbes, a primigravida aged 24 years, had x-ray pelvimetry performed in the 33rd week of pregnancy. This confirmed that there was pelvic contraction at all levels but most marked at the ischial spines; the true conjugate was 9.5 cm., the interischial 8.3 cm. and the biparietal at that time 8.1 cm.

Ultrasonic measurement of the biparietal 7 weeks later (i.e. 2 days after term) was 9.43 cm. At 41 weeks the membranes were punctured with a view to inducing labour, but the liquor amnii was meconium stained and the foetal heart immediately became irregular. Caesarean section was, therefore, performed. A live male child weighing 7 pounds 5 ounces was extracted. The calliper measurement of the biparietal diameter 2 days later was 9.23 cm.

CASE NO. 16

Mrs. Margaret McGowan, aged 27 years, had had her previous child delivered by Caesarean section because of pre-eclampsia. In her second pregnancy she did not go into labour at term. Ultrasonic measurement of the

biparietal diameter at 41 weeks was 9.6 cm. X-ray pelvimetry 2 weeks previously had shown minor contraction at the pelvic inlet and gave the biparietal diameter as 9.0 cm.

At 42 weeks the patient was delivered by Caesarean section because of delay in the first stage of labour. The child weighed 6 pounds 12 ounces. The calliper measurement of the biparietal 6 days later was 9.1 cm.

CASE NO. 17

Mrs. Elizabeth Swan, a primigravida aged 24 years, was admitted at 36 weeks because of severe pre-eclampsia. Her blood pressure was 170/115 mm. of mercury and there was 5 grammes per litre of albumen in the urine. She also had a contracted pelvis. X-ray showed an asymmetrical platypelloid pelvis with a flat sacrum: the true conjugate was 9.1 cm. Ultrasonic measurement of the biparietal at 37 weeks was 9.0 cm. At 38 weeks, labour was induced and the patient had a forceps delivery of a live female child weighing 5 pounds 9 ounces. A calliper measurement of the biparietal on the 5th day was 8.7 cm.

Had there been disproportion in this case, Caesarean section rather than induction of labour would have been the treatment of choice.

GROUP 4

CARDIAC DISEASE

Patients with cardiac disease were good subjects for this study in that they were in hospital either repeatedly or for a prolonged period during pregnancy and it was therefore possible to examine them frequently and study the growth of the foetal head.

So far as foetal growth is concerned, most of these patients were normal, but it has been thought advisable to classify them as a separate group because they were confined to bed for long periods and because the effect of their altered haemodynamics on the uterine and placental circulation is unknown.

CASE NO. 1

Mrs. Janet Logan, a primigravida aged 38 years, had severe mitral stenosis and was admitted to hospital in the 29th week of pregnancy in congestive cardiac failure. Bed rest, and the administration of Digitalis and diuretics effected some improvement but her condition remained precarious and she had repeated episodes of failure. She spent the rest of her pregnancy in hospital. Labour commenced on the expected date, but after 6 hours, gross foetal distress was evident and Caesarean section was performed. A live male child weighing 6 pounds 15 ounces was extracted. The patient made a satisfactory recovery.

INDICATION FOR CEPHALOMETRY

To study foetal growth.

RESULT

Ten measurements were made at weekly intervals as illustrated in Fig. 21 . There was no convincing evidence of growth in the last 4 weeks of pregnancy.

CASE No. 2

Mrs. Catherine Martin, aged 28 years, was admitted to hospital in the 27th week of her first pregnancy on account of haemoptysis. She was found to have mitral stenosis with marked pulmonary congestion. She responded to treatment and was dismissed at 31 weeks. She continued to attend as an out-patient. At 38 weeks she

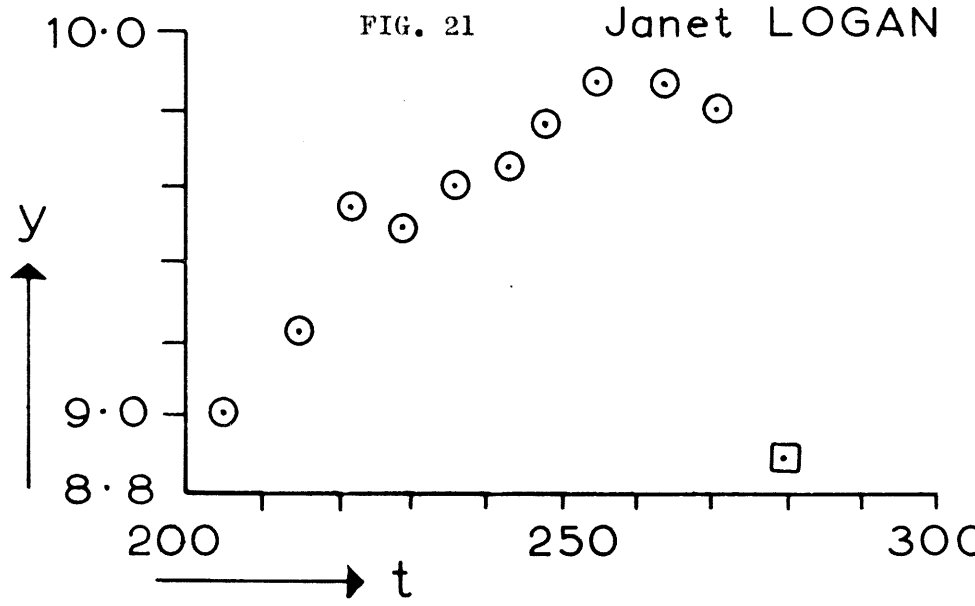


FIG. 21. Primigravida aged 38 years, with severe mitral stenosis. Note the decreasing rate of growth of the foetal biparietal diameter as term approaches. The patient was delivered by Caesarean section and a calliper measurement 24 hours after birth was 0.9 cm. less than the last estimate by ultrasound - a rather more marked decrease than usual.

was re-admitted for rest before delivery. Labour began 6 days past the expected date and she had a spontaneous vertex delivery of a live male child weighing 7 pounds 2 ounces. Mother and baby progressed well during the puerperium.

INDICATION FOR CEPHALOMETRY

To study foetal growth.

RESULT

Six measurements were obtained between the 30th and 39th week of pregnancy, indicating progressive increase. (Fig. 22).

CASE NO. 3

Mrs. Helena Currie, aged 28 years, was in her fifth pregnancy. She had had 2 early miscarriages and 2 normal pregnancies, the birth weights of the babies being 5 pounds 2 ounces and 5 pounds 13 ounces. She had a history of rheumatic heart disease and was admitted at the 31st week of pregnancy with severe decompensation. She responded well to treatment but remained in hospital throughout the rest of her pregnancy. Nine days before her expected date of delivery the foetal heart became inaudible and 3 days later she went into labour and had a spontaneous vertex delivery of a stillborn female child weighing 7 pounds.

The cause of the intra-uterine death was obscure. Postmortem examination showed no anatomical abnormality

FIG. 22 Catherine MARTIN

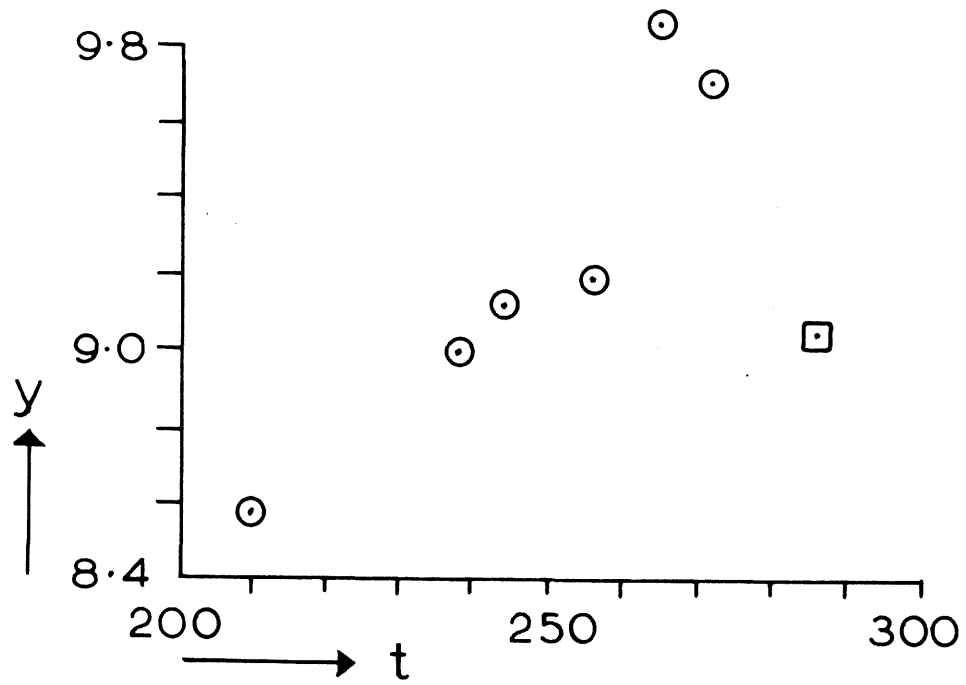


FIG. 23 Helena CURRIE

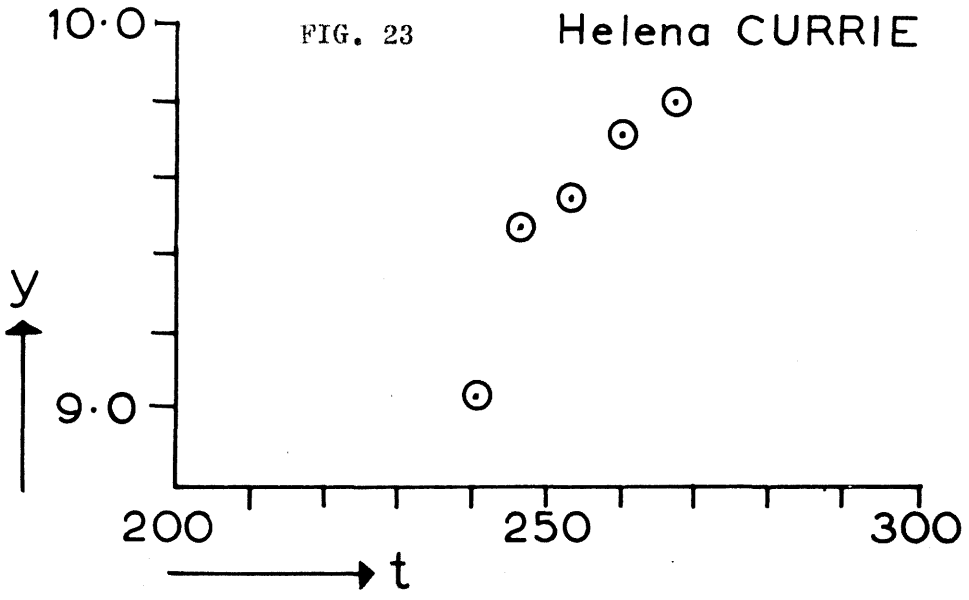


FIG. 22. Repeated estimates of the biparietal diameter in a cardiac patient: pregnancy otherwise normal.

FIG. 23. Normal growth pattern in a cardiac patient. Unexplained intrauterine death occurred 4 days after the last estimate recorded here.

of the foetus.

INDICATION FOR CEPHALOMETRY

To study foetal growth.

RESULT

Five measurements were made from the 34th to 38th week, indicating steady growth. The last measurement was made 4 days before the death of the foetus. (Fig. 23).

CASE NO. 4

Mrs. Mary McTaggart, a primigravida aged 25 years, who was known to have rheumatic heart disease, was admitted to hospital at 34 weeks on account of haemoptysis. Despite treatment, she had recurrent episodes of decompensation until after delivery. She also had megaloblastic anaemia and was treated with Folic Acid. Labour began 11 days before the expected date and the patient was delivered by Vacuum extraction of a live female child weighing 6 pounds 1 ounces.

INDICATION FOR CEPHALOMETRY

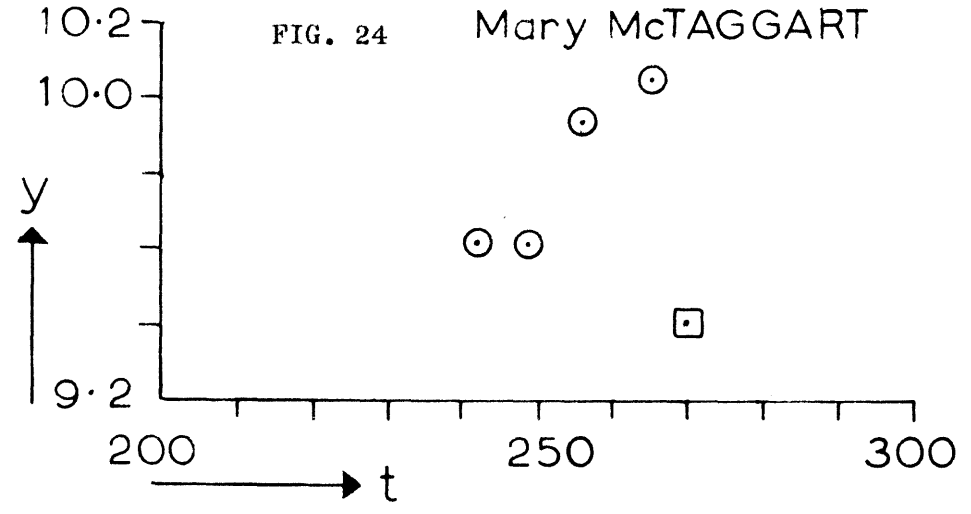
To study foetal growth.

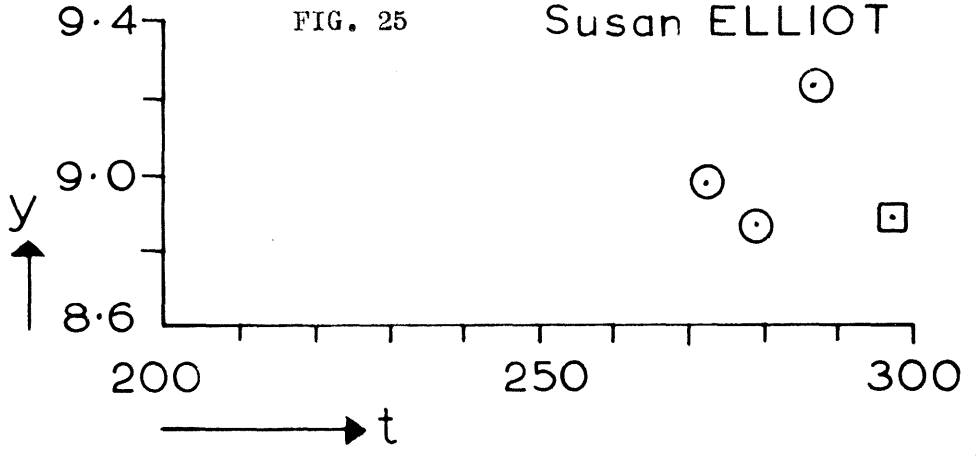
RESULT

Four measurements from the 34th to 37th week, confirming foetal growth. (Fig. 24).

CASE NO. 5

Mrs. Susan Elliot, aged 23 years, had 2 children whose birth weights were $6\frac{1}{4}$ and $6\frac{3}{4}$ pounds. She had





FIGS. 24 & 25. Repeated estimates of the biparietal diameter in patients admitted to hospital with cardiac disease.

well-compensated mitral stenosis and was admitted 8 days before her expected date in her third pregnancy. She had a normal labour and delivery 16 days after term. The child, a girl, weighed 7 pounds 4 ounces.

INDICATION FOR CEPHALOMETRY

To assess foetal size at term.

RESULT

Three measurements were made. There appeared to be some growth after term. (Fig. 25).

CASE NO. 6

Mrs. Sarah Douglas, aged 40 years, had mitral stenosis and incompetence. She had had 6 previous full-time pregnancies. The babies weighed between 5 and 9 pounds. She spent most of her 7th pregnancy in hospital on account of recurrent cardiac decompensation. Five days past her expected date she had a normal labour and spontaneous vertex delivery of a live female child weighing 8 pounds 13 ounces.

INDICATION FOR CEPHALOMETRY

To assess foetal size at term.

RESULT

Three measurements between 38 and 40 weeks showed no evidence of growth.

Calliper measurements of the baby's biparietal diameter were made after birth. The first measurement was made at 10 hours: the second, at 55 hours showed

a decrease of 0.17 cm. (Fig. 26).

CASE NO. 7

Mrs. Ann Kerr, aged 41 years, had severe valvular disease of the heart and also chronic hypertension. She had had 6 previous mature pregnancies and 1 miscarriage. All her babies had been small, from 5 to 6½ pounds. She was admitted at 27 weeks in congestive cardiac failure. Her blood pressure on admission was 170/100 millimetres of mercury and did not settle with rest. Her condition remained grave, albuminuria appeared, and eventually it was decided to terminate the pregnancy.

At 29 weeks Caesarean section was performed and a live male child weighing 2 pounds 5 ounces was extracted. The baby developed respiratory distress soon after birth and died after 13 hours. At 7½ hours ultrasonic examination showed no abnormal echoes within the brain. (This case is referred to in the section on the ultrasonic examination of the brain in the newborn).

INDICATION FOR CEPHALOMETRY

To assess foetal size in a case where termination of pregnancy was being considered and it was hoped to postpone the operation long enough to obtain a live child.

RESULT

Three measurements were made antenatally, confirming that the foetal head was very small. No steady growth pattern was elicited. (Fig. 27).

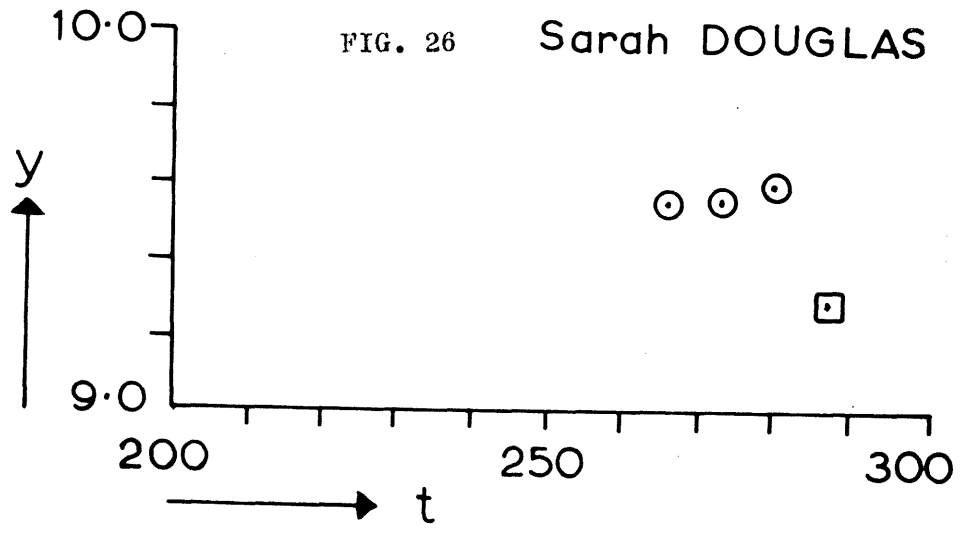
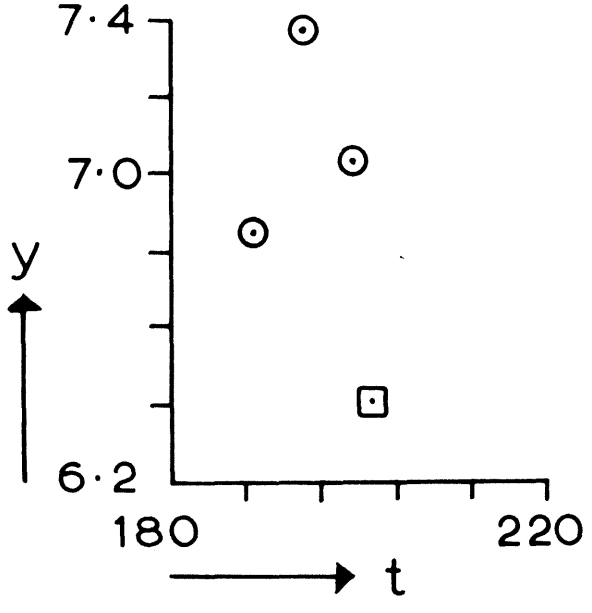


FIG. 26 Sarah DOUGLAS



Ann KERR FIG. 27

FIG. 26. Patient aged 40 years with severe cardiac disease. No significant increase in the biparietal diameter in the last 3 weeks of pregnancy.

FIG. 27. Cardiac patient in whom pregnancy had to be terminated at 29 weeks because of severe hypertension. Very small mobile foetus probably responsible for inconsistency of results.

GROUP 5

ANAEMIA

It is generally accepted that maternal anaemia during pregnancy has no appreciable effect on foetal growth. Most women who have anaemia during pregnancy produce babies of normal weight. However, there is some evidence to show that the prematurity rate is increased. For example, KLEIN (1962), reviewing 68,241 live births in the State of Georgia for which maternal prenatal haemoglobin levels were recorded, found that the incidence of premature births associated with a maternal haemoglobin level of 10 grammes per cent or above, was 7.6 per cent: the incidence of premature births associated with a maternal prenatal haemoglobin level below 10 grammes per cent was 13.8 per cent. This suggests that it is untreated anaemia which is probably related to prematurity - together with other factors such as nutrition and social class. In treated cases, such as the few described here, babies do not seem to be premature - some of the cases described were, in fact, postmature.

CASE NO. 1

Miss Ann Young, aged 22 years, had no antenatal care until the 32nd week of pregnancy when she was admitted to hospital in a grossly anaemic state, her haemoglobin being 2.6 grammes per cent. Shortly after admission she showed signs of cardiac failure and was treated with blood transfusion, diuretics and oxygen. After this episode her condition improved markedly. The anaemia was megaloblastic in type and treatment with Folic Acid was given throughout the rest of her pregnancy: however, this, combined with further transfusion and a course of intramuscular iron failed to produce an entirely satisfactory response and it became evident that haemolysis was taking place. The diagnosis of congenital non-spherocytic haemolytic anaemia was made and in the later weeks of pregnancy she was given one pint of blood every third day. Under this regime, her haemoglobin remained around 9.5 grammes per cent. A total of 16 pints of blood was given antenatally.

Labour did not ensue at term and at 42 weeks surgical induction was performed: a normal labour followed, terminating in the spontaneous vertex delivery of a live female child weighing 8 pounds 3 ounces. Blood loss during and after the third stage was normal. The patient was transferred to a medical unit during the puerperium so that further investigations could be

undertaken.

INDICATION FOR CEPHALOMETRY

To study foetal growth and assess foetal size in the last month of pregnancy in a case of severe anaemia under treatment.

RESULT

Six measurements were obtained antenatally. These suggested that the baby was big. There was no evidence of a significant increase in the biparietal diameter from the 39th to the 42nd week. (Fig. 28).

CASE NO. 2

Mrs. Euphemia Shillady, aged 36 years, had had 5 previous babies weighing between 8 and 9½ pounds. At 34 weeks in her 6th pregnancy she was found to have a marked anaemia (Haemoglobin 7.0 grammes per cent) which was megaloblastic in type. She was treated with iron and Folic Acid. The baby was thought to be rather small and her dates were questioned, but she gave a clear menstrual history. Before term she disappeared from the clinic and did not attend again until 44 weeks, when she was brought in for induction. She responded quickly to this and had a spontaneous vertex delivery of a live male child weighing 8 pounds 3 ounces. Her haemoglobin before labour was 12.9 grammes per cent.

INDICATION FOR CEPHALOMETRY

To study foetal growth in a case of anaemia where

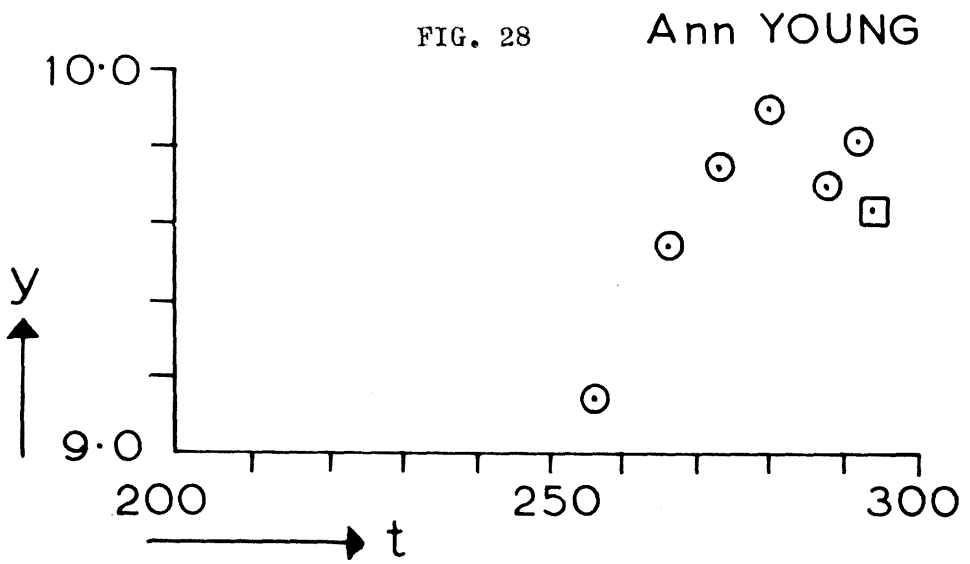


FIG. 28. Case of severe anaemia under treatment. Pregnancy continued to 42 weeks and the foetal biparietal diameter appeared to decrease after term.

the baby appeared clinically to be smaller than expected.

RESULT

Six measurements made antenatally showed steady and progressive growth. The initial measurement at 34 weeks was smaller than expected, but the finding of a regular increase lent colour to the idea that the patient might have mistaken her dates. The biparietal diameter increased by 0.6 cm. between the 39th and 44th week. (Fig. 29).

CASE NO. 3

Mrs. Violet Broadley, aged 27 years, was admitted at 36 weeks in her third pregnancy on account of megaloblastic anaemia. Her haemoglobin was 6.5 grammes per cent. She responded well to treatment with iron and Folic Acid. Nine days past her expected date she had a normal labour and delivery of a live male child weighing 7 pounds.

INDICATION FOR CEPHALOMETRY

To study foetal growth in the last month of pregnancy in a case of anaemia under treatment.

RESULT

The 4 measurements obtained suggested that the foetus was of mature size and was growing. (Fig. 30).

FIG. 29 Euphemia SHILLADY

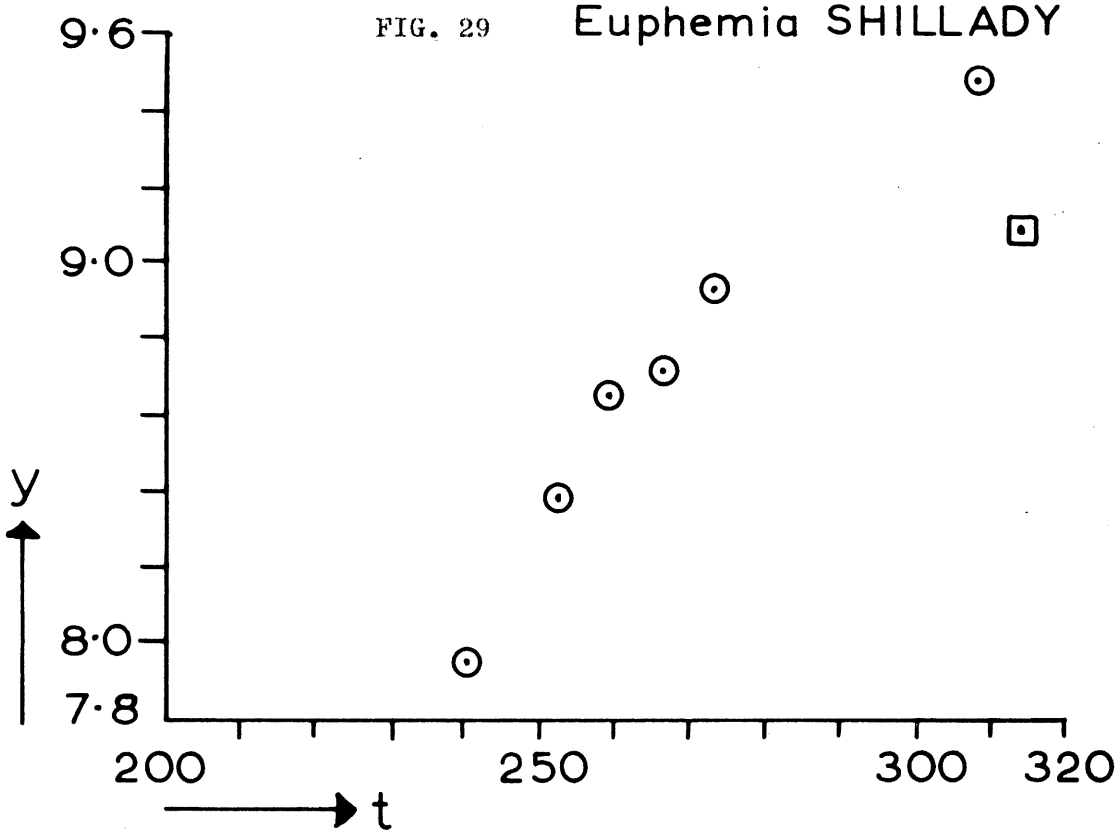


FIG. 30 Violet BROADLEY

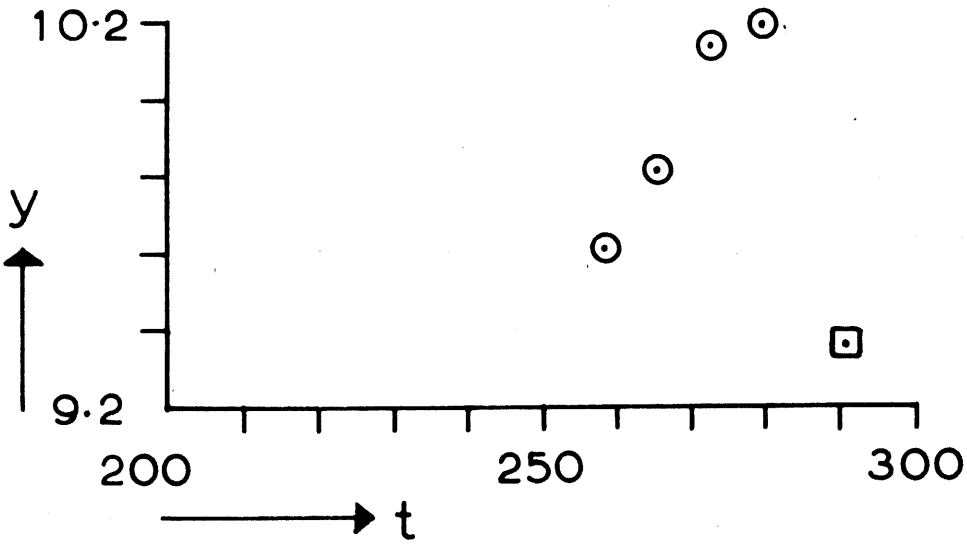


FIG. 29. Foetal growth demonstrated in a case of anaemia. The dates were probably mistaken.

FIG. 30. Normal foetal growth in a case of anaemia under treatment.

CASE NO. 4

Mrs. Hutchison, aged 32 years, had a previous normal delivery of an $8\frac{1}{2}$ pound baby. During her second pregnancy she became severely anaemic and was admitted at 33 weeks with a haemoglobin of 5.8 grammes per cent. Her anaemia was treated with Folic Acid and intramuscular iron and she made satisfactory progress. She was re-admitted 12 days past her expected date and 4 days later had a forceps delivery of a baby weighing 7 pounds 15 ounces.

INDICATION FOR CEPHALOMETRY

The patient was fat and it was very difficult to assess foetal size and presentation.

RESULT

Two measurements were made antenatally.

1. At 34 weeks - 9.02 cm.
2. At 41 weeks - 9.45 cm.

The calliper measurement at birth was 9.41 cm.

GROUP 6

ANTEPARTUM HAEMORRHAGE

Until recent years, the sole consideration of the obstetrician in treating the haemorrhages of the later months of pregnancy was to save the life of the mother. Nowadays, however, when blood transfusion and the increased use of Caesarean section have contributed to reduce the maternal mortality dramatically, much more attention is given to the well-being of the child.

In cases of placenta praevia, expectant treatment as advocated by MACAFEE (1945) has been universally accepted; the object of this treatment is to carry on the pregnancy until the child is mature enough to survive, provided that this can be done without endangering the mother's life. By this means, MACAFEE was able to reduce the foetal death rate from over 50 per cent to less than 10 per cent. Expectant treatment is also pursued in cases of revealed accidental haemorrhage, where bleeding ceases and the child remains alive, and it has been recognised that the foetal mortality in these cases is, in present day conditions, higher than that from placenta praevia.

MURDOCH and FOULKES (1952), drawing attention to this fact, remarked that "There is no type of haemorrhage in which the foetus is not at risk". This is the view held also in the unit in which the following

cases were treated. Patients suffering from antepartum haemorrhage are admitted to hospital and in all except the earliest and mildest cases, kept in hospital until delivery. During their stay, an attempt is made, by x-ray placentography, speculum examination and by constant observation to determine the cause of the bleeding. In some cases, the diagnosis is not reached until delivery. The usual practice is to make a vaginal examination under anaesthesia at the 38th week and on this basis to perform Caesarean section, rupture the membranes or, in a few cases, continue expectant treatment.

The fact remains, however, that in any case of antepartum haemorrhage active intervention may be necessary at any time as a recurrence of bleeding, perhaps completely without warning, may endanger the lives of mother and child. With this in mind, it is most useful to have an estimate of the size of the baby at repeated intervals during the patient's stay in hospital. Ultrasonic cephalometry was performed in the following series of cases in an attempt to provide this information.

CASE NO. 1

Mrs. Gladys Easton, aged 28 years, had two previous normal pregnancies, the babies' weights being $5\frac{3}{4}$ and 8 pounds respectively. She was admitted at 28 weeks in her third pregnancy because of painless vaginal bleeding. Bleeding settled soon after admission. Speculum examination failed to reveal any local cause for it. In view of the early stage of the pregnancy and the complete subsidence of bleeding she was dismissed after 8 days. She continued to attend as an out-patient.

At 35 weeks she was re-admitted with further slight painless bleeding and it was decided to treat her conservatively in the first instance. Nineteen hours after admission she awoke from sleep with a fit of coughing and suddenly had a profuse haemorrhage of about 4 pints. Blood was rapidly transfused under pressure and the patient was taken to theatre where vaginal examination revealed an anterior placenta praevia (type II). Lower uterine segment Caesarean section was performed and a lethargic male child weighing $5\frac{1}{2}$ pounds was extracted. The baby developed the respiratory distress syndrome and died 34 hours later. The mother made a good recovery.

INDICATION FOR CEPHALOMETRY

To observe foetal growth in a case of early ante-partum haemorrhage.

RESULT

Seven consecutive weekly measurements were obtained indicating progressive growth from the 29th to the 35th week. The last measurement was made on the day of the patient's second admission and only a few hours before delivery. The size of the baby was estimated as being mature. Clear echoes were always obtained from this case: the readings were made, as it proved, through the placenta which did not show up on the A-scope trace, being, as one would expect, transonic and containing no pronounced discontinuities in density.
(Fig.31).

CASE NO. 2

Mrs. Catherine Cavanagh, aged 33 years, was in her tenth pregnancy but had only one living child. This baby, from her first pregnancy, weighed 5 pounds at birth. All the rest of her pregnancies miscarried at varying stages between the 16th and 28th week.

Because of the history of recurrent miscarriages, Shirodkar's operation of cervical suture was performed in the 12th week of her 10th pregnancy. She was allowed home soon after but was re-admitted at 26 weeks because of bleeding and abdominal pain: she had several episodes of slight bleeding but this settled after a week. At 31 weeks she was dismissed home again.

Ten days later when attending as an out-patient she

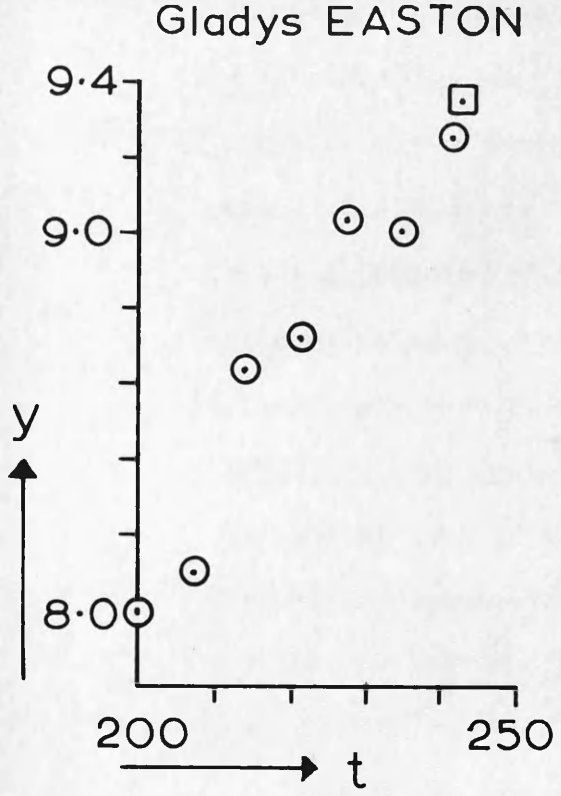


FIG. 31. Case of placenta praevia delivered by Caesarean section. Progressive increase in biparietal diameter demonstrated antenatally.

FIG. 32

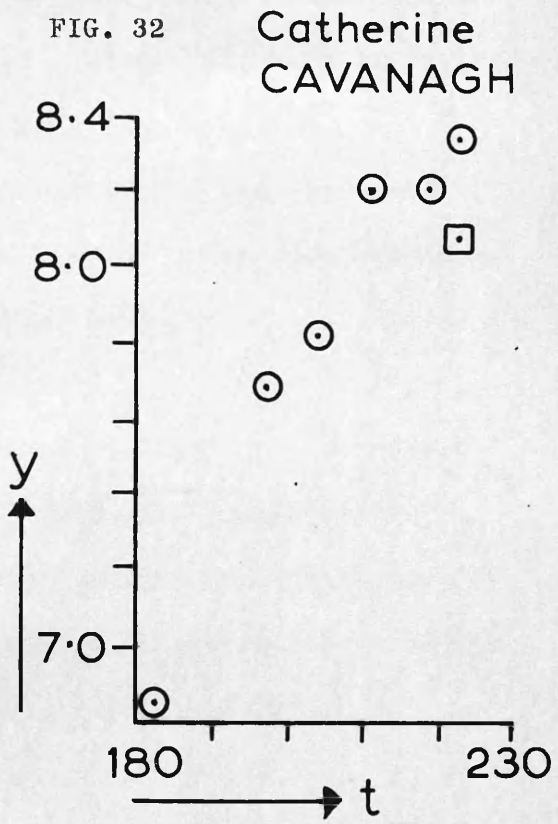


FIG. 32. Recurrent antepartum haemorrhage due to placenta praevia. Delivery by Caesarean section in the 33rd week. Foetal growth demonstrated.

had a brisk haemorrhage as she stepped on to the couch for abdominal examination. She was admitted immediately. Later in the day the foetal heart became very slow and it was decided to deliver the infant as it seemed of a size that might survive, although premature. Classical Caesarean section was performed and a live child weighing 4 pounds was extracted. There was a type III placenta praevia. Mother and baby did well.

INDICATION FOR CEPHALOMETRY

The history in this case of the loss of 8 out of 9 previous pregnancies made it of great interest to know whether the baby was growing normally.

RESULT

Growth was observed and at first appeared to be rapid. The last of the 6 antenatal measurements was made on the day when the patient was re-admitted with haemorrhage and enabled a correct prediction to be made about the size of the baby. (Fig. 32).

CASE NO. 3

Mrs. Mary Scouller, aged 23 years, had one child whose birth weight (at term) was 7 pounds 5 ounces. She was admitted at 30 weeks in her second pregnancy because of painless vaginal bleeding and remained in hospital until delivered. X-ray placentography at 34 weeks revealed a posterior placenta praevia. There was no further bleeding. Vaginal examination under

anaesthesia at 38 weeks confirmed the presence of a posterior placenta praevia (type II). Lower uterine segment Caesarean section was immediately performed and a live male child weighing 7 pounds 12 ounces was extracted. Mother and baby did well.

INDICATION FOR CEPHALOMETRY

To observe foetal growth in a case of antepartum haemorrhage.

RESULT

Steady increase was shown in 6 antenatal measurements. By the time that it was decided to effect delivery, there was evidence that the baby was well grown. (Fig. 33).

CASE NO. 4

Mrs. Rosalind Elder, aged 29 years, had had one previous 6 pound baby at term. She was admitted with painless vaginal bleeding at 32 weeks in her second pregnancy. X-ray examination at 34 weeks was suggestive of placenta praevia (type II) and this was confirmed when a vaginal examination was made under anaesthesia at 38 weeks. Caesarean section was performed and a live male child weighing 6 pounds 9 ounces was delivered. Mother and child were dismissed home well.

INDICATION FOR CEPHALOMETRY

To observe foetal growth in a case of antepartum haemorrhage.

FIG. 33 MARY SCOULLER

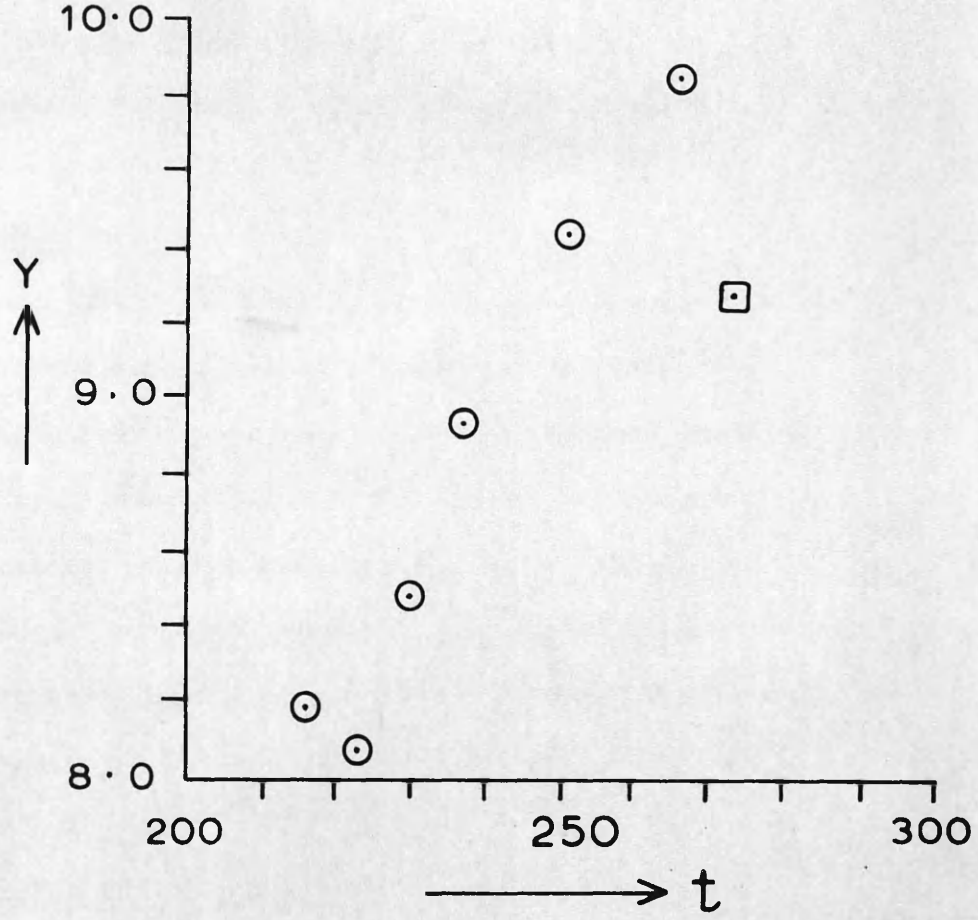


FIG. 33. Growth of foetal biparietal diameter observed from 30 weeks onwards in a case of placenta praevia.
Delivery by Caesarean section.

RESULT

An increase of 0.5 cm. was observed between the 34th and the 38th week. In the first 24 hours after birth repeated calliper measurements showed a decrease of 0.4 cm. in the biparietal diameter. This was one of the first cases in which the early alteration of the diameter after birth was clearly demonstrated. (Fig. 34).

CASE NO. 5

Mrs. Sheila Callaghan, aged 25 years, was admitted at 32 weeks in her second pregnancy on account of vaginal bleeding, the cause of which remained unknown. She stayed in hospital for the rest of her pregnancy. Examination under anaesthesia at 38 weeks showed no evidence of placenta praevia. Artificial rupture of the membranes was performed and 13 hours later there was a spontaneous delivery of a live male child weighing 6 pounds 15 ounces.

INDICATION FOR CEPHALOMETRY

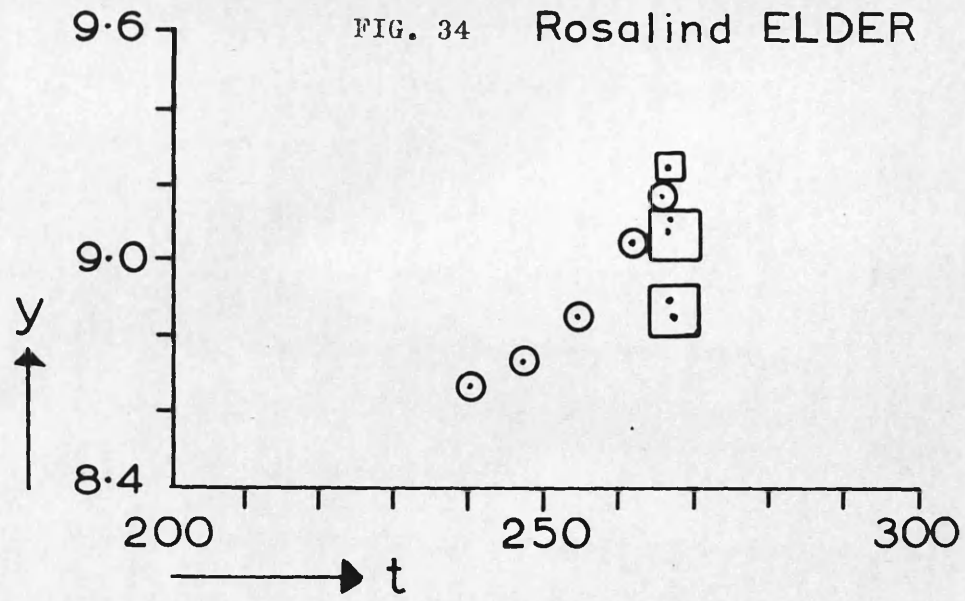
To observe foetal growth.

RESULT

Four measurements showed an increase of 0.6 cm. between the 34th and 38th week and suggested that the baby was mature. (Fig. 35).

CASE NO. 6

Mrs. Margaret Riach, aged 29 years, had had 2



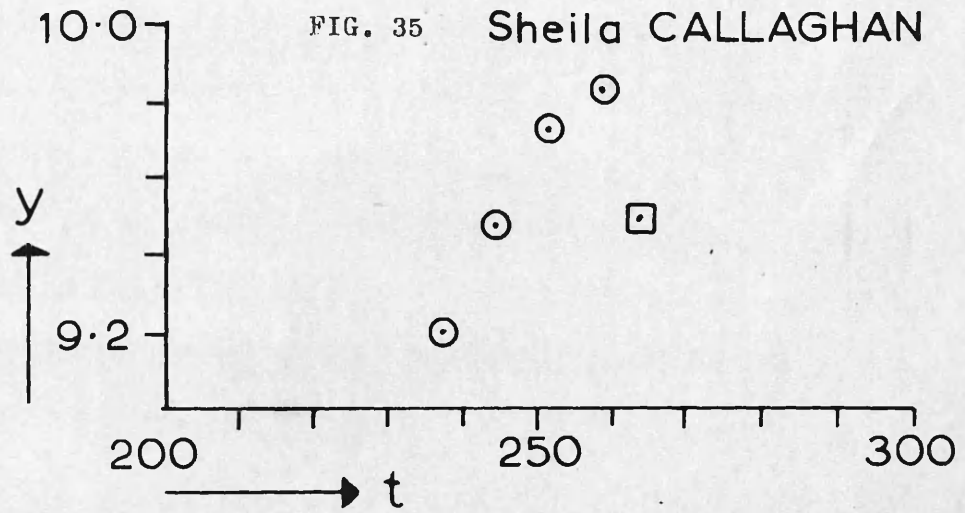


FIG. 34. Placenta praevia. Delivery by Caesarean section. Note progressive antenatal increase in the biparietal diameter and sharp decrease during the first 24 hours after birth.

FIG. 35. Antepartum haemorrhage - cause unknown. Antenatal estimates of biparietal diameter suggest normal foetal growth.

previous babies weighing 7 pounds and 6½ pounds at birth. Her menstrual cycle was irregular and the expected date in her third pregnancy was uncertain. At about 30 weeks by dates she was admitted to hospital because of painless vaginal bleeding. The uterus seemed larger than suggested by the dates and x-ray showed a single foetus about 34 weeks mature: there was also evidence of a posterior placenta praevia. Ultrasonic cephalometry also showed a diameter larger than would be expected at 30 weeks. Four weeks later, therefore, when it seemed probable that 38 weeks maturity had been reached, Caesarean section was performed after confirming the presence of a type III posterior placenta praevia by examination under anaesthesia. A live male child weighing 7 pounds 3 ounces was extracted.

INDICATION FOR CEPHALOMETRY

To assess foetal size in a case of antepartum haemorrhage where the maturity of the pregnancy was doubtful.

RESULT

Cephalometry helped here in assessing maturity and in confirming foetal growth. (Fig. 36).

CASE NO. 7

Mrs. Susannah Pollock, aged 31 years, had had four previous normal deliveries at term and two early miscarriages. All her babies had weighed 6 pounds at

FIG. 36 Margaret RIACH

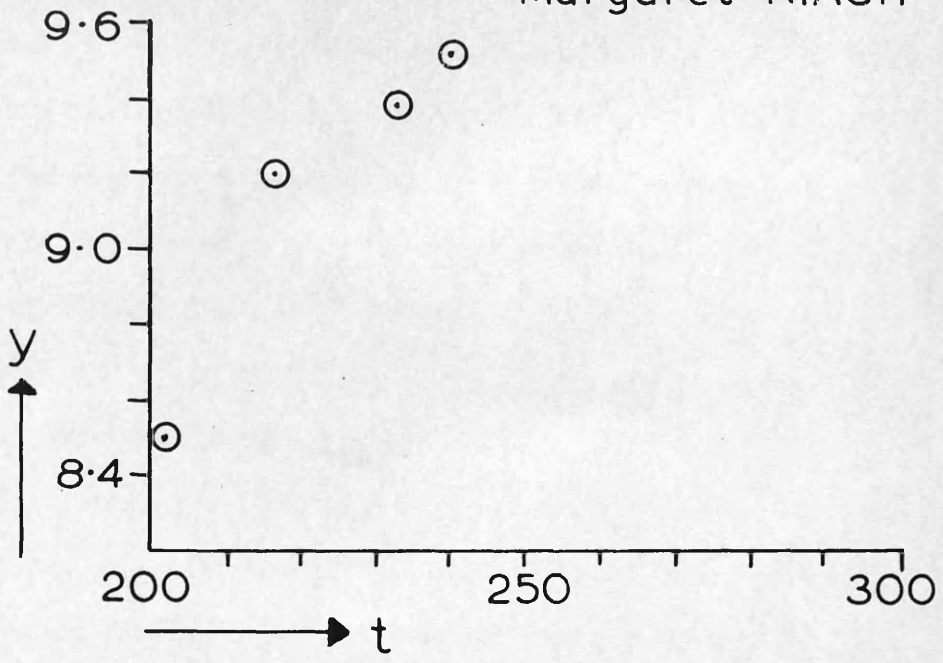


FIG. 37 Susannah POLLOCK

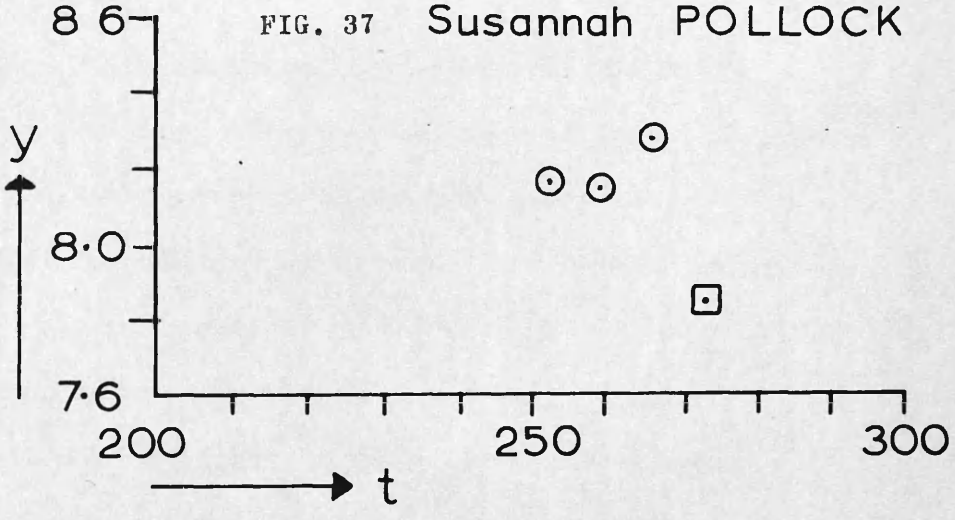


FIG. 36. Placenta praevia. Doubtful dates. Measurements larger than expected for dates. 7lb 3oz baby at 34 weeks by dates - probably really 38 weeks.

FIG. 37. Placenta praevia. Measurements suggest small baby not growing much. Caesarean section. 4lb 7oz baby.

birth. She was admitted at 32 weeks in her 7th pregnancy on account of antepartum haemorrhage. X-ray showed a posterior placenta praevia. This was confirmed when the patient was delivered by Caesarean section at 38 weeks because of a recurrence of bleeding. The baby, a girl, weighed 4 pounds 7 ounces.

INDICATION FOR CEPHALOMETRY

To observe foetal growth.

RESULT

Three measurements showed that the head was small and growth was negligible. In the event, delivery had to be effected in the maternal interest. (Fig. 37).

CASE NO. 8

Mrs. Helen McConnon, aged 40 years, had a bad obstetric history. Four of her nine children had been stillborn as the result of abruptio placentae.

She was admitted at 30 weeks in her 10th pregnancy with yet another antepartum haemorrhage associated with abdominal pain. Fortunately, she responded to conservative treatment, despite several more small haemorrhages while in hospital, where she remained for the rest of her pregnancy, although most unwilling to stay. At 36 weeks, surgical induction was performed. A normal labour followed and she had a spontaneous vertex delivery of a live male child weighing 6 pounds 3 ounces.

INDICATION FOR CEPHALOMETRY

To assess size and growth of the foetus in a case of antepartum haemorrhage in which it seemed very likely that premature intervention would be required.

RESULT

Unfortunately, this was not a very useful series. The first measurement was based on a very doubtful picture and was almost certainly an error. Two subsequent measurements were in good agreement with each other. A few hours after the third examination there was some more vaginal bleeding which the patient attributed to the ultrasonoscopy. In view of this, no attempt was made to repeat the examination. (Fig. 38).

CASE NO. 9

Mrs. Rosemary McLuskey, aged 29 years, was admitted with antepartum haemorrhage at the 32nd week. She had had 3 previous children who weighed between 5 and 7 pounds at birth. Her last baby had been delivered by Caesarean section because of foetal distress and her convalescence on that occasion was complicated by wound sepsis.

The usual investigations were negative: at 38 weeks artificial rupture of the membranes was performed but, as labour did not supervene the following day, the patient was delivered by Caesarean section of a live male child weighing 6 pounds 7 ounces.

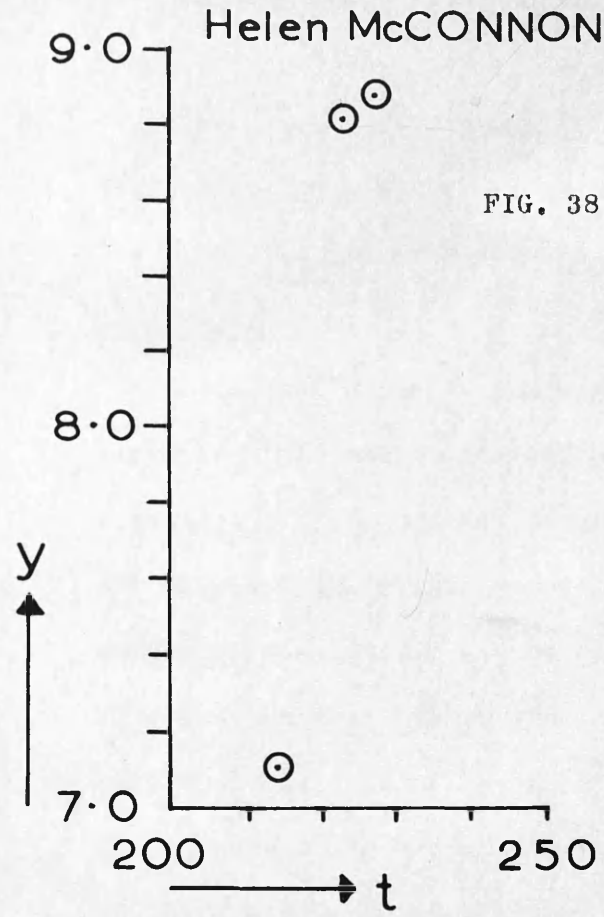


FIG. 38. Accidental haemorrhage. Incomplete series. First measurement probably erroneous.

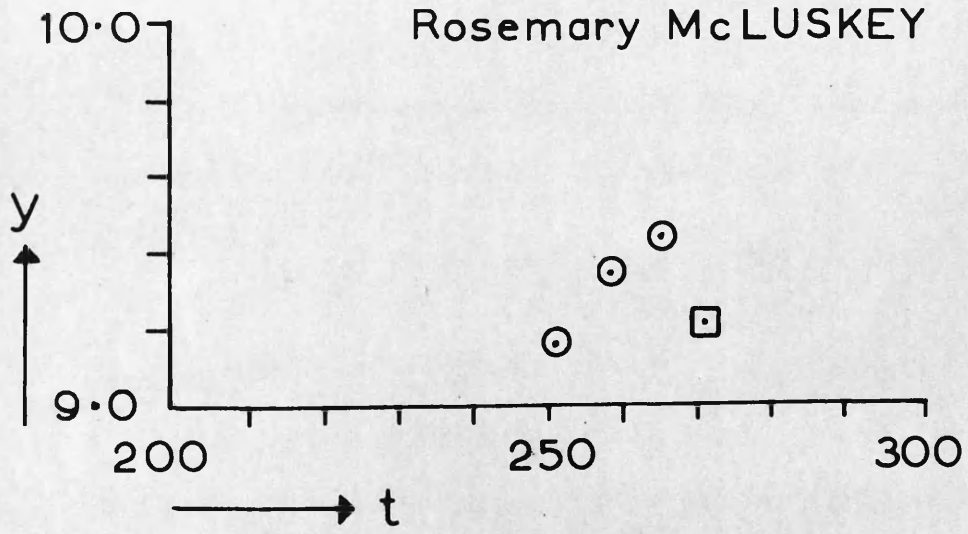


FIG. 39. Accidental haemorrhage. Previous Caesarean section. Evidence of normal foetal growth.

INDICATION FOR CEPHALOMETRY

To assess foetal size and growth.

RESULT

Three consistent readings were obtained from the 36th to the 38th week. (Fig. 39).

CASE NO. 10

Mrs. Anne Noone, a primigravida aged 20 years, was admitted at 34 weeks with abdominal pain and vaginal bleeding. The diagnosis of mixed accidental haemorrhage was made but the symptoms settled after 24 hours and the pregnancy continued. Labour commenced spontaneously at 36 weeks and there was a spontaneous delivery of a live male child weighing 5 pounds 2 ounces. The placenta showed several infarcts.

INDICATION FOR CEPHALOMETRY

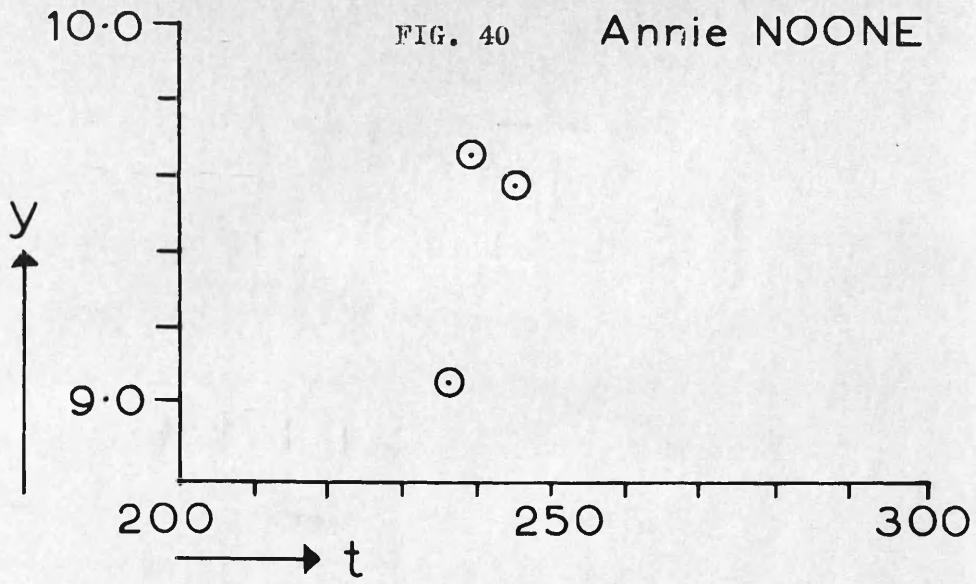
To assess foetal size and growth.

RESULT

This patient always proved difficult to examine and the results were inconstant and rather unhelpful. (Fig. 40).

CASE NO. 11

Mrs. Kimiho McCully, a primigravida aged 26 years, had antepartum haemorrhage at 33 weeks and again at 37 weeks. X-ray examination showed no evidence of placenta praevia. The membranes were ruptured at 38 weeks



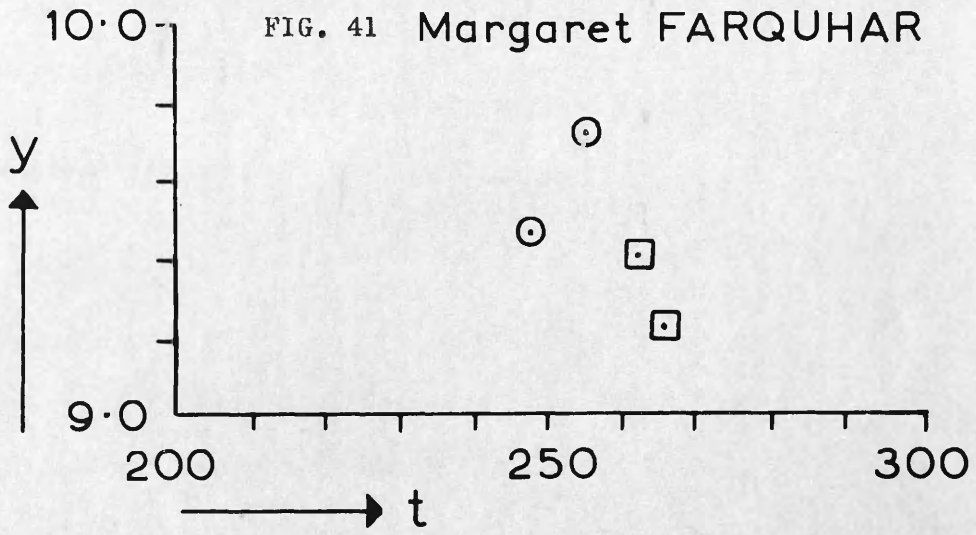


FIG. 40. Accidental haemorrhage. Rather inconsistent results.

FIG. 41. Placenta praevia. Caesarean section. Note postnatal decrease in biparietal diameter.

to induce labour. A prolonged inco-ordinate labour followed and after 50 hours the patient was delivered by Caesarean section of a live male child weighing 5 pounds 15 ounces.

INDICATION FOR CEPHALOMETRY

The biparietal diameter was measured shortly after each episode of bleeding, to help in assessing foetal size as delivery was being considered on both these occasions.

RESULT

At 34 weeks	9.21 cm.
At 37 weeks	9.58 cm.
Calliper measurement 14 days later (6 days after delivery)	9.15 cm.
Ultrasound measurement 14 days later (6 days after delivery)	8.97 cm.

CASE NO. 12

Mrs. Mary Watson, aged 34 years, had had 4 babies weighing between 8 and 9 pounds. In her fifth pregnancy she had slight vaginal bleeding at 31 weeks. She was kept in hospital till 34 weeks but as placentography was negative and there had been no further bleeding she was dismissed. Labour began 3 days after her expected date and she had a spontaneous vertex delivery of a live female child weighing 7 pounds 11 ounces.

INDICATION FOR CEPHALOMETRY

To assess foetal size.

RESULT

Measurements made at 33 and 34 weeks were rather inconsistent.

At 33 weeks	8.8 cm.
At 34 weeks	9.2 cm.
Three days after delivery	9.1 cm. by calliper.

CASE NO. 13

Mrs. Sadie Wineberg, aged 40 years, was in her 7th pregnancy. The birth weights of her babies had been between 6 and 8 pounds. She had vaginal bleeding at 33 weeks and investigations showed that this was due to a cervical polypus, which was removed. She was re-admitted in premature labour at 36 weeks and delivered a boy weighing 5 pounds 6 ounces.

INDICATION FOR CEPHALOMETRY

The baby seemed small and the intention was to follow foetal growth until term.

RESULT

It is interesting to note that there was little change in the biparietal diameter during the period under observation, rather like the findings that have been made in patients at or past term.

At 34 weeks	8.65 cm.
At 35 weeks	8.63 cm.

Seven days later (24 hours after birth) -

8.61 cm. by ultrasound.

8.78 cm. by calliper.

CASE NO. 14

Mrs. Moira Mulholland or Murphy, aged 27 years, had had 2 small babies ($4\frac{1}{2}$ and $5\frac{1}{2}$ pounds) at term in her previous pregnancies. She had painless vaginal bleeding at 34 weeks in her third pregnancy. X-ray examination showed a posterior placenta praevia. A week later she had a further, quite profuse bleeding and examination under anaesthesia confirmed the x-ray findings (type II placenta praevia). Artificial rupture of the membranes was performed and a fairly rapid labour soon followed, ending in the normal delivery of a live female child weighing 5 pounds 10 ounces.

INDICATION FOR CEPHALOMETRY

To assess foetal size.

RESULT

It was very difficult to interpret the echoes obtained from the foetal head in this case and little reliance could be placed on the findings.

At 34 weeks 8.36 cm.

At 35 weeks (patient in labour) 8.1 cm.

No external measurement was obtained.

CASE NO. 15

Mrs. Mary Heaney, aged 38 years, was admitted at 33 weeks in her 6th pregnancy. No cause was found for the bleeding. Labour began spontaneously at 35 weeks and there was a spontaneous vertex delivery of a live

female child weighing 4 pounds 2 ounces, who progressed well.

INDICATION FOR CEPHALOMETRY

To observe foetal growth.

RESULT

The onset of premature labour prevented the continuance of this study. The measurements obtained were consistent with the baby's weight, although no external measurement was obtained to confirm the ultrasonic findings.

At 33 weeks 7.75 cm.

At 35 weeks (2 days before delivery) 8.29 cm.

CASE NO. 16

Mrs. Margaret Farquhar, aged 30 years, was admitted at 34 weeks in her 4th pregnancy with painless vaginal bleeding. The lie of the foetus was variable and x-ray appearances were suggestive of placenta praevia. In the 38th week there was a further haemorrhage. Examination under anaesthesia confirmed placenta praevia (type III). A live male child weighing 6 pounds 13 ounces was delivered by Caesarean section.

INDICATION FOR CEPHALOMETRY

To assess foetal size.

RESULT

Two measurements, at 35 and 36 weeks suggested that the baby was of mature size. Two measurements were made

after birth which confirmed the antenatal predictions. (Fig. 41).

CASE NO. 17

Mrs. Wilma Brown, aged 25 years, had 2 previous normal pregnancies. In her third pregnancy she was admitted at 24 weeks with a threatened abortion. Symptoms subsided after a week and she was dismissed. She was re-admitted in premature labour at 28 weeks and had a spontaneous delivery of a female child weighing 3 pounds, who died after 2 hours.

INDICATION FOR CEPHALOMETRY

To see whether foetal head echoes were clearly recognisable at 24 weeks.

RESULT

Characteristic echoes were obtained and measurements obtained (although not easily) on 2 occasions. This indicated the probable presence of a normal foetus in this case.

At 24+ weeks 6.6 cm.

At 25 weeks (5 days later) 6.5 cm.

(This case of threatened abortion and the two which follow have been included in the antepartum haemorrhage group for want of a separate classification).

CASE NO. 18

Mrs. Helena White, aged 38 years, had 3 previous

normal pregnancies and deliveries. She was admitted at 27 weeks in her 4th pregnancy because of threatened miscarriage. She had repeated episodes of bleeding after admission and at 31 weeks went into premature labour and delivered a baby weighing 3 pounds 10 ounces. The child was stillborn although the foetal heart was heard just before delivery. Examination of the placenta showed evidence of mixed accidental haemorrhage.

INDICATION FOR CEPHALOMETRY

Threatened miscarriage and recurrent bleeding in a very fat patient in whom palpation was difficult.

RESULT

Three measurements at 28, 29 and 30 weeks were 6.6 cm., 7.1 cm. and 6.6 cm. respectively. The pictures were remarkably clear considering the difficulty in finding the foetal head by palpation, but were thought not to be entirely reliable.

CASE NO. 19

Mrs. Agnes Sharp, aged 33 years, had 2 previous normal pregnancies and deliveries. At 26 weeks in her third pregnancy she was admitted with threatened abortion and premature rupture of the membranes. Despite this, pregnancy continued for another 6 weeks. At 32 weeks she delivered a female child weighing 3 pounds 12 ounces. The baby died 40 hours after birth.

INDICATION FOR CEPHALOMETRY

The threat of premature labour was a very strong one here and cephalometry was undertaken to help in assessing the size of the baby.

RESULT

Measurements were difficult to obtain and were not all consistent, but the calliper measurement at birth was consistent with the ultrasonic measurement 2 days previously.

CASE NO. 20

Mrs. Jessie Macallister, aged 30 years, had 3 children who were all under 6 pounds at birth. She was admitted at 32 weeks in her 4th pregnancy with a slight antepartum haemorrhage. Labour commenced 4 days later and she had a spontaneous delivery of a live female child weighing 4 pounds 2 ounces.

Ultrasonic cephalometry on admission estimated the biparietal at 8.1 cm.: this was consistent with the foetal weight, but no calliper measurement was obtained.

CASE NO. 21

Mrs. Alice Morrison, aged 33 years, was admitted at 27 weeks by dates in her 4th pregnancy with a profuse antepartum haemorrhage. X-ray suggested that the correct maturity was 34 weeks. At 31 weeks by

dates the biparietal diameter was measured by ultrasound as 9.3 cm. This was in accord with the x-ray findings and inconsistent with the patient's dates. She was eventually delivered by Caesarean section 4 weeks after admission, having been found to have a placenta praevia. The baby weighed 6 pounds 5 ounces. No calliper measurement was obtained.

CASE NO. 22

Mrs. Agnes Vallery, a primigravida aged 20 years, had vaginal bleeding following routine pelvic examination at 36 weeks. The biparietal diameter was estimated by ultrasound as 9.6 cm. Three days later the patient had a spontaneous vertex delivery of a live female child weighing 6 pounds 13 ounces. The calliper measurement 24 hours after birth was 9.1 cm.

CASE NO. 23

Mrs. Janet Boyd, aged 24 years, was admitted at 37 weeks in her second pregnancy with painless vaginal bleeding. The baby seemed small and at 38 weeks the ultrasonic estimate of the biparietal was 8.2 cm. Next day, examination under anaesthesia revealed a placenta praevia (grade 2) and Caesarean section was performed. The child, a female, weighed 5 pounds 9 ounces. The calliper measurement of the biparietal 3 days later was 8.02 cm.

CASE NO. 24

Mrs. Chrys Brisbane, aged 24 years, had a small antepartum haemorrhage at term in her 3rd pregnancy. The ultrasonic measurement of the biparietal on admission was 9.8 cm. Two days later, following artificial rupture of the membranes, she had a spontaneous vertex delivery of a boy weighing 7 pounds 6 ounces. The calliper measurement on the 5th day of life was 9.2 cm.

CASE NO. 25

Mrs. Jean Cafferty, aged 32 years, had 4 previous full-time confinements: the babies all weighed between 5 and 6½ pounds. She had an antepartum haemorrhage at 36 weeks in her 5th pregnancy. There was no radiological evidence of placenta praevia. In the 38th week the ultrasonic estimate of the biparietal diameter was 9.1 cm. Six days later, following examination under anaesthesia and induction of labour, the patient had a spontaneous vertex delivery of a live male child weighing 5 pounds 14 ounces. The calliper measurement 24 hours after birth was 9.1 cm.

GROUP 7

HYPERTENSION AND PRE-ECLAMPSIA

It will be noted that some of the most severe examples of these conditions are not included in this group at all but appear under "placental insufficiency". The reason is that, in a study whose primary object was to investigate foetal growth and development it seemed more logical to separate all those cases in which the foetal size appeared to be grossly deficient for the stage of pregnancy into a group by themselves rather than to classify them under the predominant maternal condition.

All the patients in the present group were admitted to hospital because of hypertension and allied clinical signs. No attempt has been made to subdivide the group into cases of pre-eclampsia, essential hypertension and chronic renal disease although the relevant facts about each case are stated individually.

In many of the cases which follow, there was anxiety about the condition of the baby at some stage during pregnancy and ultrasonic cephalometry was often able to provide useful information even if it was only to confirm that the baby was of normal size and that its growth was not being adversely affected.

Placental insufficiency is always to be feared in cases of pre-eclampsia and essential hypertension, but

is difficult to detect. BROWNE and VEALL (1958) demonstrated that the placental blood flow was reduced in both these conditions and MORRIS et al. (1955) under similar circumstances observed a reduction in blood flow to the myometrium. Investigations of this type are difficult and complicated and do not offer a very practical service to the clinician. Nor do hormone assays, as there seems to be considerable doubt at present about their significance - for example, pregnanediol excretion is now thought to be unreliable and oestriol is more favoured (COYLE, 1962).

It is very difficult for the obstetrician to select, by either clinical or laboratory methods, those cases of hypertension and pre-eclampsia in which foetal growth is likely to suffer. It is hoped that ultrasonic cephalometry will provide a useful objective standard of foetal size and growth in these cases and may be widely used for this purpose.

CASE NO. 1

Mrs. Catherine Bisset, aged 37 years, had one previous normal pregnancy - with no sign of pre-eclampsia - which terminated in the spontaneous delivery of a live child weighing $6\frac{1}{2}$ pounds. She was admitted at 34 weeks in her second pregnancy on account of hypertension (blood pressure 150/95 mm. mercury) and generalised oedema. There was no albuminuria. With rest in hospital the oedema disappeared but the blood pressure remained around the same level. At 39 weeks labour was induced by puncture of the membranes and 34 hours later she had a spontaneous vertex delivery of a live male child weighing 6 pounds 3 ounces.

INDICATION FOR CEPHALOMETRY

Pre-eclampsia.

RESULT

Clinically, the baby seemed of average size and this was confirmed by the foetal head measurements which also, with the exception of the last, showed some slight increase, although growth appeared to be slower than usual. The pregnancy was continued as long as seemed reasonable, but induction of labour near term was certainly wise. (Fig. 42).

CASE NO. 2

Mrs. Agnes Borthwick, aged 40 years, had 2 previous babies, the last delivered by Caesarean section for

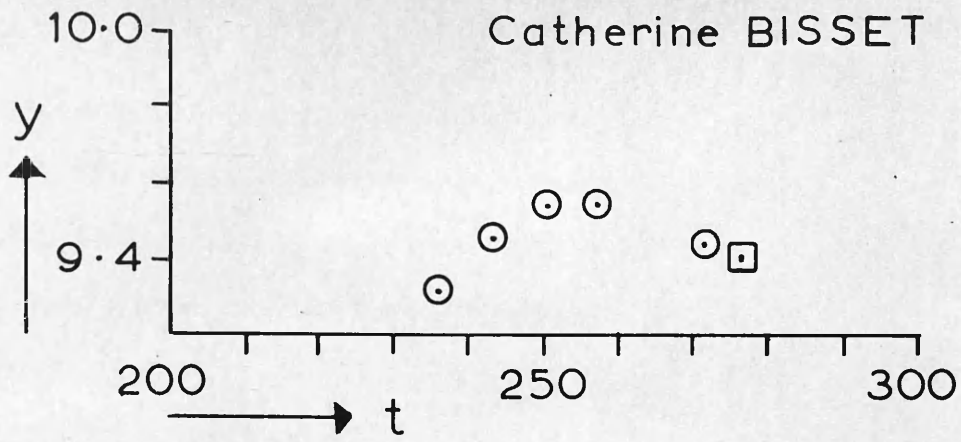


FIG. 42. Pre-eclampsia. Decrease in growth of foetal biparietal diameter inthe later weeks of pregnancy. Surgical induction at 39 weeks.

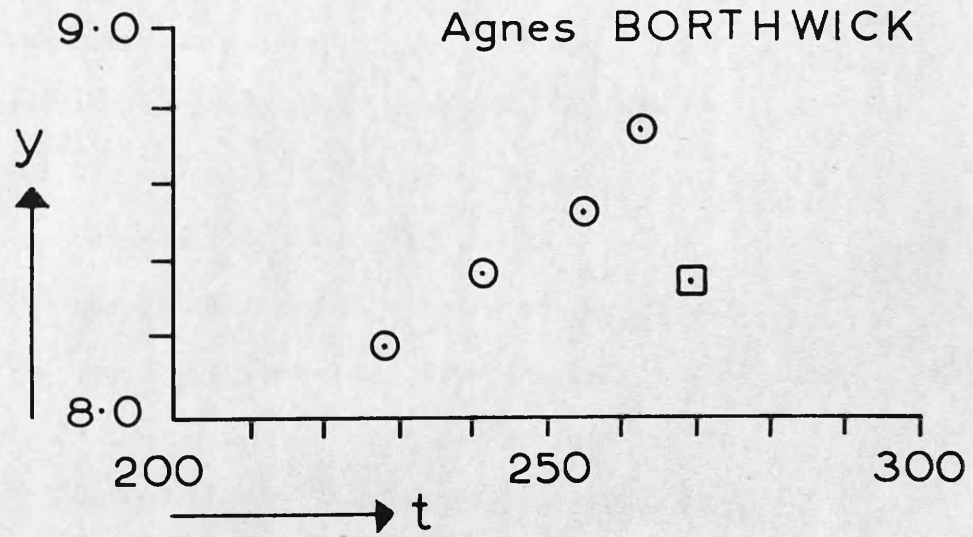


FIG. 43. Essential hypertension. Evidence of continued foetal growth throughout. Spontaneous labour at 38 weeks.

placenta praevia. She was under observation during her third pregnancy on account of essential hypertension, her blood pressure generally being around 150/90 mm. mercury. There was no oedema or albuminuria. Labour commented 2 weeks before the expected date and she had a spontaneous vertex delivery of a live female child weighing $5\frac{1}{2}$ pounds.

INDICATION FOR CEPHALOMETRY

Essential hypertension: baby seemed rather small.

RESULT

Foetal growth as judged by increase in the biparietal diameter was progressive, although the child was small. (Fig. 43).

CASE NO. 3

Mrs. Agnes Mair, a primigravida aged 25 years, was admitted in the 35th week of pregnancy because of essential hypertension. Her blood pressure remained elevated - between 140/75 and 150/90 mm. mercury - after admission and at 38 weeks it was decided to induce labour as the child seemed to be well grown. After puncture of the membranes, an inco-ordinate labour followed and the patient was eventually delivered by Caesarean section of a live female child weighing 7 pounds 10 ounces.

INDICATION FOR CEPHALOMETRY

Essential hypertension.

RESULT

Repeated measurements confirmed that the foetal head was of normal size and there was evidence of growth. The patient was examined antenatally on 4 occasions - at weekly intervals - but unfortunately, on the second of these (at 36 weeks) no reliable measurement could be obtained. (Fig. 44).

CASE NO. 4

Mrs. Iris Archer, aged 46 years, had one child and also had had 2 miscarriages. She was admitted at 33 weeks in her 4th pregnancy with pre-eclampsia (blood pressure 140/90 mm. mercury and considerable oedema). She did not respond well to conservative treatment and in the 37th week it was decided to induce labour. Following artificial rupture of the membranes she had a spontaneous vertex delivery of a live female child weighing 6 pounds 5 ounces.

INDICATION FOR CEPHALOMETRY

Pre-eclampsia.

RESULT

This was a most difficult patient to examine as the head was engaged from an early stage. The measurements obtained were not consistent and were of little value other than to support the clinical impression that the baby was of mature size. (Fig. 45).

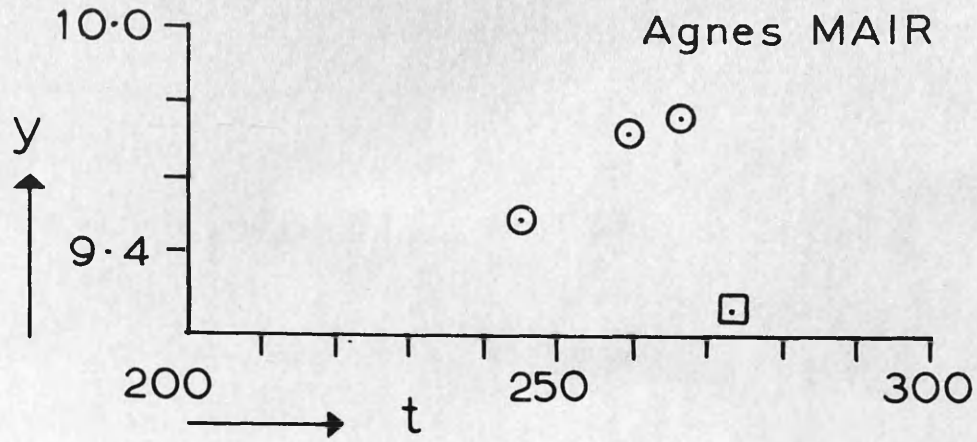


FIG. 44. Essential hypertension.
Evidence of progressive foetal growth.

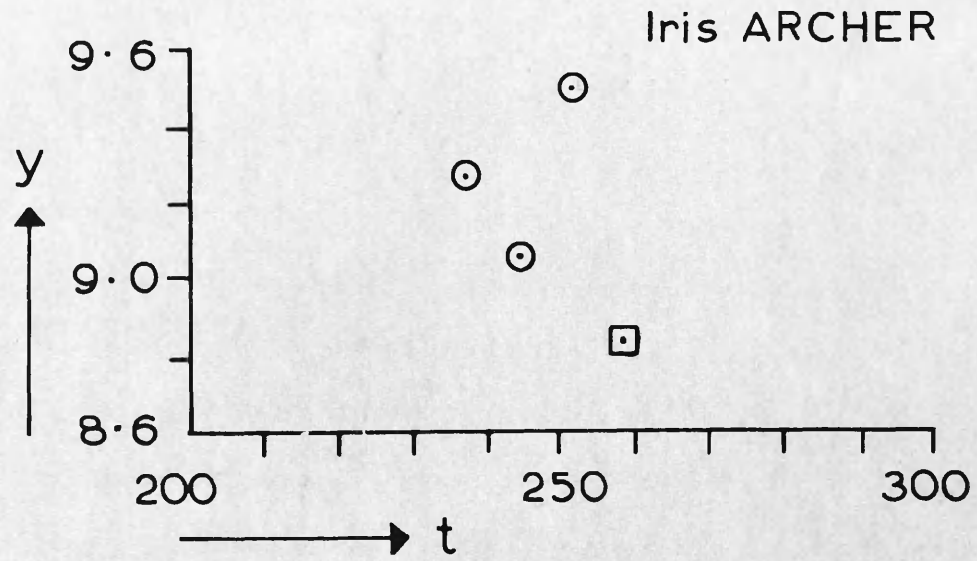


FIG. 45. Pre-eclampsia.
Patient very difficult to examine and measurements inconsistent.

CASE NO. 5

Mrs. Grace Hunter, aged 24 years, had been known to have chronic nephritis for 2 years: her last child had been delivered by Caesarean section at 36 weeks because of this condition. She was admitted at 16 weeks in her second pregnancy with a blood pressure of 170/110 mm. mercury, albuminuria of 2 G. per litre and a blood urea of 68 mg. per 100 ml. She remained in hospital throughout her pregnancy and was delivered by Caesarean section at 36 weeks of a live male child weighing 5 pounds 6 ounces.

INDICATION FOR CEPHALOMETRY

To measure the foetal head at an early stage in pregnancy.

RESULT

Measurements were made in the 24th, 25th and 26th weeks - being 5.78 cm., 6.55 cm. and 6.50cm. respectively. While these were quite probable results, the mobility of the baby made the examination technically difficult and the interpretation of the echoes obtained was not easy. The series was not continued.

CASE NO 6

Mrs. Isabel Mullaney, a primigravida aged 34 years, was admitted at 28 weeks with severe pre-eclampsia. She was grossly oedematous, her blood pressure was 230/120 mm. mercury and she had 3 G. per litre of albumen

in the urine. Conservative treatment, including the use of the hypotensive drugs Apresoline and Puroverine, had no effect and in the 32nd week Caesarean section was performed. The child, a male weighing 2 pounds 11 ounces, showed no sign of life, although the foetal heart had been heard before operation.

INDICATION FOR CEPHALOMETRY

Severe pre-eclampsia, where premature delivery would certainly be indicated.

RESULT

Measurements at 30 and 31 weeks were 7.7 cm. and 7.5 cm., indicating a size compatible with the dates. The external calliper measurement made in the post mortem room 12 hours after birth was 6.8 cm.

CASE NO. 7

Mrs. Margaret Kieran was aged 41 years. Her only previous child, who weighed 6 pounds at birth, had been delivered by Caesarean section because of inco-ordinate labour. She was admitted at 35 weeks in her second pregnancy with pre-eclampsia (blood pressure 150/100 mm. mercury and moderate oedema). At 38 weeks she was delivered by Caesarean section of a live female child weighing 4 pounds 15 ounces.

INDICATION FOR CEPHALOMETRY

Pre-eclampsia. The timing of delivery was under discussion.

RESULT

At 35+ weeks the biparietal was estimated to be 8.9 cm.

" 37+ " " " " " " " 9.2 cm.

These figures were slightly larger than one would expect from the weight of the child. No calliper measurement has been recorded.

CASE NO. 8

Mrs. Pauline Bonner, aged 29 years, had 2 previous pregnancies. Her first baby, at term, was only 4 pounds and died in a few days: her second baby, also at term, was 6 pounds. Her blood pressure during her third pregnancy was normal until 39 weeks, when it suddenly rose to 160/110 mm. mercury and she was admitted to hospital. Labour was induced by puncture of the membranes and she had a spontaneous vertex delivery of a live female child weighing 7 pounds 7 ounces.

INDICATION FOR CEPHALOMETRY

The case was started as one of normal pregnancy.

RESULT

At 36 weeks the biparietal was estimated at 9.17 cm. Nine days later the breech was found presenting and the biparietal diameter was measured at 9.34 cm. Easy external cephalic version was performed and the measurement made again: it was 9.39 cm. All this was before the patient developed hypertension but knowledge that the baby was of mature size was valuable. The external

calliper measurement made 24 hours after birth was 9.0 cm.

CASE NO. 9

Mrs. Marjory Lang, a primigravida aged 23 years, was admitted at 35 weeks because of hypertension (170/110 mm. mercury). Ultrasonic examination at 37 weeks gave a biparietal measurement of 10.2 cm. suggesting that the baby was large. The patient was delivered by Caesarean section following a prolonged inco-ordinate labour a week later. The baby weighed $8\frac{1}{2}$ pounds. No calliper measurement was obtained.

CASE NO. 10

Mrs. Alexandrina Wilson, a primigravida aged 22 years, was admitted at 36 weeks with moderate pre-eclampsia. Ultrasonic cephalometry measured the biparietal diameter at 9.4 cm., indicating a mature size of child. Two weeks later, labour was induced and the patient had a spontaneous vertex delivery of a girl weighing 7 pounds 5 ounces. The calliper measurement 24 hours after birth was 9.2 cm.

CASE NO. 11

Mrs. Catherine Wood, aged 41 years, had one previous pregnancy - twins both weighing more than 6 pounds were delivered at 43 weeks. She was admitted at 32 weeks in

her second pregnancy on account of hypertension. The blood pressure was 160/100 mm. mercury on admission, but settled with rest. Abdominal palpation was very difficult and the presenting part could not be felt, nor could the size of the baby be estimated as she was fat and the uterine outline was not clear. Ultrasonic examination revealed a vertex presentation, the biparietal being 8.0 cm. - normal for the duration of pregnancy. The patient was discharged after a week and remained well for the rest of her pregnancy. She had a spontaneous delivery at term of a girl weighing 6 pounds 12 ounces.

CASE NO. 12

Mrs. Elizabeth Henderson, aged 36 years, was admitted at 35 weeks in her 7th pregnancy with severe pre-eclampsia. Her blood pressure was 170/110 mm. mercury, there was albuminuria of 2 grammes per litre and she had considerable oedema. Her previous 3 pregnancies had been complicated by hypertension and the last had ended in the stillbirth of a 5 pound baby at term, due to mixed accidental haemorrhage.

On account of her history and the severity of her toxaemia, it was feared that she might have placental insufficiency, and colour was lent to this view by the fact that the baby seemed small on palpation. The ultrasonic measurement of the biparietal diameter was 9.17 cm. and the opinion was given that the baby seemed

quite well grown and would probably be about 6 pounds. Labour was induced 6 days later and she had a spontaneous delivery of a live female child weighing 5 pounds 10 ounces. The calliper measurement of the biparietal on the 4th day of life was 9.12 cm.

CASE NO. 13

Mrs. Ruth Auld, aged 34 years, had had 6 children whose birth weights were between 8 and 10 pounds. She was admitted at 38 weeks in her 7th pregnancy because of essential hypertension (her blood pressure being 140/100 mm. mercury), and variable lie. Ultrasonic examination on admission estimated the biparietal diameter at 9.28 cm. Labour was induced at term and she had a spontaneous delivery of a live female child weighing 7 pounds 15 ounces. The calliper measurement of the biparietal diameter 24 hours after birth was 9.21 cm.

CASE NO. 14

Miss Christina McColl, aged 20 years, was admitted to hospital with marked pre-eclampsia when she was supposedly 5 months pregnant. However, the uterus was about 36 weeks size and the ultrasonic measurement of the biparietal was 9.3 cm. As the child seemed of mature size and as her condition deteriorated, labour was induced. She was delivered by Vacuum extraction of a live female child weighing 6 pounds 9 ounces. No

measurement of the biparietal was obtained after birth.

CASE NO. 15

Miss Margaret Connelly, a primigravida aged 21 years, had an irregular menstrual cycle and was not sure of the date of her last period. She was admitted to hospital with hypertension (blood pressure 140/90 mm. mercury) and oedema. The uterus was enlarged to the size of a pregnancy about 36 weeks. The ultrasonic measurement of the biparietal was 9.3 cm. Labour was induced 2 weeks after this measurement was made and a male child weighing 6 pounds 5 ounces was delivered spontaneously. The calliper measurement of the biparietal on the second day of life was 9.5 cm.

CASE NO. 16

Mrs. Joan Jones, aged 35 years, was admitted at 38 weeks in her first pregnancy with mild pre-eclampsia. The ultrasonic measurement of the foetal biparietal diameter on admission was 9.5 cm., indicating quite a large baby. Labour was induced the following day and she had a forceps delivery of a live male child weighing $8\frac{1}{2}$ pounds.

CASE NO. 17

Mrs. Sarah Wilson, aged 43 years, had previously had 6 babies who were all big at birth - between 9 and

9½ pounds. She was admitted 10 days before her expected date in her 7th pregnancy because of essential hypertension (blood pressure 160/95 mm. mercury) and breech presentation. With the breech presenting, the ultrasonic measurement of the foetal biparietal diameter was 10.2 cm., indicating another big baby. On the following day, external cephalic version was performed and the membranes were ruptured to induce labour. After 17½ hours in labour the foetal head was still above the pelvic brim and foetal distress was evident. Caesarean section was performed and a live female child weighing 10 pounds 7 ounces was extracted. The calliper measurement of the biparietal diameter 24 hours after birth was 9.9 cm.

GROUP 8

PLACENTAL INSUFFICIENCY

It is upon the placenta that the foetus depends for its nutrition. McCANCE (1962) in his Lumleian lectures on "Food, Growth and Time", which contain a masterly review on the subject of foetal nutrition and development, points out that the amount of food reaching the foetus depends upon the quantities of available nutrients in the maternal blood flowing through the placenta and the size, age and other parameters of this organ which together go to make up its "efficiency". Dysfunction of the placenta, therefore, may result in failure of foetal growth, and in recent years the concept of "placental insufficiency" has been much talked of, although as RUSSELL (1962) says, this can mean different things to different people, and in the present state of ignorance about details of placental function, can be described only in the crudest terms. That such a process occurs in some cases of toxaemia, where the baby is small and the placenta infarcted, has long been recognised but lately more attention has been paid to cases of perinatal death of unknown cause where there is no evidence of toxaemia and yet the baby fails to grow.

More than half of perinatal deaths occur in premature infants, as has been pointed out by CROSSE and MACKINTOSH (1954) and others. Although the majority of the neonatal deaths in these infants are due to the pulmonary syndrome of the newborn, with or without cerebral haemorrhage, there

remains a substantial number of stillbirths and neonatal deaths whose ultimate cause is failure of foetal nutrition via the placenta. Attention has been focussed recently on the fact that some babies who are premature by weight are undoubtedly of mature gestational age and may show some of the characteristic features associated with postmaturity. BUTLER (1962) stated that one third of all "premature" babies weighing 2.5 kg. or less were born at 39 weeks or more of gestation and that these babies had a mortality rate two and a half times the average. SJOSTEDT et al. (1958) used the term "dysmature" to describe such infants; in their study of dysmature infants they found a decreased oxygen saturation in the cord blood, whereas there was an increase in haemoglobin, plasma pentoses, protein-bound hexoses, bilirubin and non-protein nitrogen - all this being probably indicative of ischaemia or destruction of placental tissue.

The cause of death in cases of placental insufficiency has often been described as anoxia, but evidence is accumulating to suggest that lack of oxygen is only part of the picture; it seems likely that these babies starve to death in the same way as an adult does when deprived of food. SHELLEY (1961) discusses foetal glycogen reserves and their changes at birth and in anoxia. She thinks it possible that factors which reduce the glycogen content of the foetus in utero or at birth may jeopardize the infant's chances of survival after

birth and suggests that future work must determine to what extent the deleterious effects of maternal malnutrition, placental insufficiency and birth asphyxia may be the consequence of inadequate glycogen reserves. MOTT (1961) showed that the glycogen content of the heart and brain are severely depleted in anoxic newborn animals, while SCOTT (1963) has found evidence of glycogen lack on postmortem examination of babies from cases of placental insufficiency.

It is quite conceivable that in certain circumstances not only may foetal growth be inadequate, but the foetus may actually shrink in utero. McCANCE (1962) says, "Time operates in all pregnancies. The foetus can spend only a limited period in utero, and even the growth of a singleton human foetus begins to falter towards the end of its normal time there because of the ageing of the placenta, which may become so inefficient after full term that the postmature foetus may show signs of undernutrition and actually lose weight". When the placenta ages prematurely it is likely that such foetal changes occur earlier. (The decreasing head measurements in Case No. 1 in this group appear to be a striking example of shrinkage in utero.)

There is as yet no satisfactory test of placental function and the need for such a test is an urgent one. In its absence all that the obstetrician can do is to observe very closely all cases in which (whether due to

toxaemia or other factors) there appears to be failure of foetal growth and hope that by intervention at the right time it may be possible to save the child's life. It is likely that when foetal growth ceases the child is at risk. The purpose of ultrasonic cephalometry in cases of placental insufficiency is to demonstrate whether or not adequate foetal growth is taking place.

The following group is composed of cases in which clinical examination suggested that the baby was small for the dates or was failing to grow. As has already been pointed out, some of these are cases of toxaemia, but in others there was no demonstrable cause.

CASE NO. 1

Mrs. Elizabeth Grier, aged 27 years, had had one previous normal pregnancy ending in the spontaneous delivery at term of a live child weighing 5 pounds 12 ounces.

She was admitted to hospital in the 30th week of her second pregnancy with marked pre-eclampsia. Her blood pressure was 155/115 mm. mercury, she had considerable oedema and there was 0.75 G. per litre of albumen in the urine. She was treated with bed rest, diuretics and hypotensive drugs - Puroverine for the first 6 weeks and then Guanethidine. After one week in hospital the albuminuria disappeared, but she remained moderately hypertensive despite treatment. The uterus was rather small for the dates and as time went past it was suspected that the baby was not growing. In the 38th week it was decided to induce labour. Rupture of the membranes produced heavily blood stained liquor amnii. The question of immediate delivery by Caesarean section was considered but decided against as it was thought that vaginal delivery would give this baby the best start in life because of the smaller risk of respiratory complications. Labour began a few hours after induction. After 6 hours in labour the foetal heart suddenly became inaudible and 30 minutes later there was a spontaneous vertex delivery of a stillborn female child weighing 3 pounds 9 ounces. The cord was

wound three times tightly round the neck. The placenta was small, weighing only 11 ounces and had 3 large white infracts involving about one sixth of its surface.

Postmortem examination of the baby showed atelectasis, hepatic and renal necrosis and adrenal cytomegaly - the significance of the last 3 findings being obscure. The child was very thin and presented the "starved" appearance often seen in placental insufficiency.

INDICATION FOR CEPHALOMETRY

Pre-eclampsia associated with a small baby.

RESULTS

The results in this case are particularly interesting because on each of the nine occasions on which ultrasonic examination was made an absolutely clear picture was obtained and there was no difficulty whatever in interpretation or measurement.

This being so, it could be assumed that the findings were free from experimental error. The biparietal diameter increased between the 30th and 34th week, then appeared to stop growing and finally decreased. This was extremely puzzling at the time, but it is in accord with what is known of the pathological changes in cases of placental insufficiency where the baby seems literally to starve to death, losing subcutaneous fat and its stores of glucose.

The decrease in the measurements in the last 2 weeks may well have represented an actual shrinkage of the

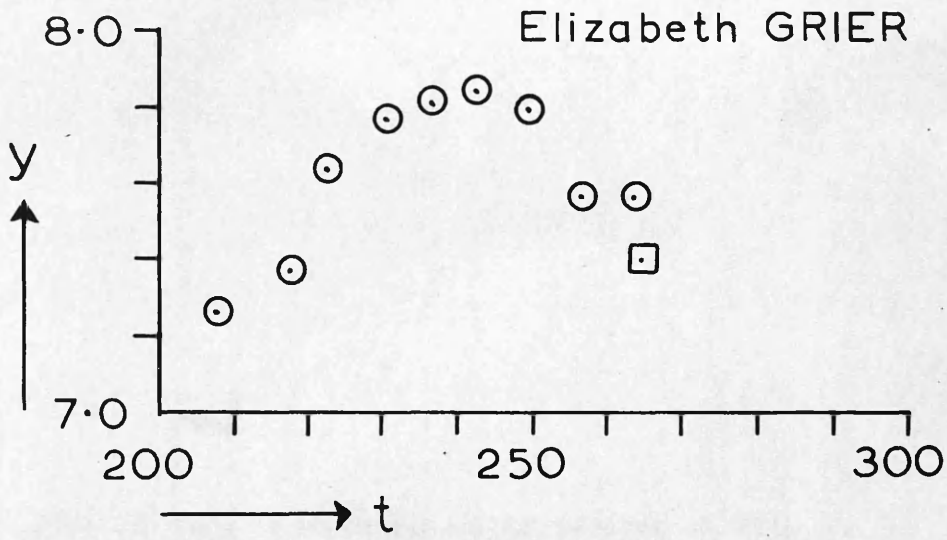


FIG. 46. Pre-eclampsia with placental insufficiency. Clear pictures were obtained on each examination. There is evidence offailure of foetal growth after the 34th week of pregnancy and eventually a decrease in the biparietal diameter, probably representing the "starvation" changes of placental insufficiency.
The foetus died during labour; its weight was 3lb 9ozs.

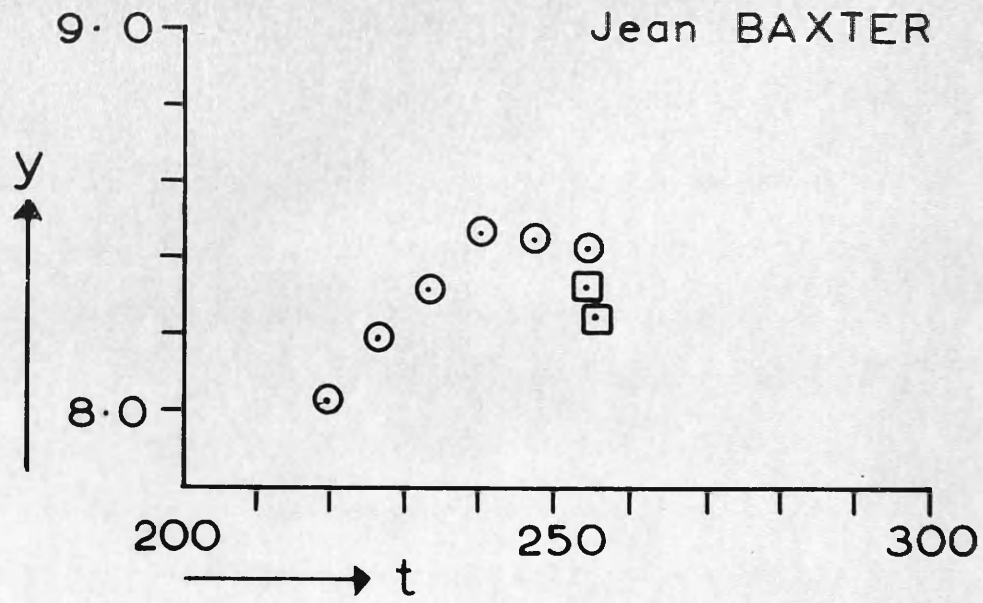


FIG. 46 (a). A rather similar pattern to FIG. 46 is shown in this recent interesting case which is not described separately in the text.
The patient was aged 36 years and had been a diabetic for 7 years. Her only other pregnancy occurred when she was in her teens and had been terminated by hysterotomy at 16 weeks.
She was admitted at 30 weeks in her second pregnancy with mild pre-eclampsia and instability regarding her insulin requirements. At 36 weeks she was found to have Rhesus antibodies. Two days later surgical induction was carried out but only thick meconium was obtained: Caesarean section was therefore performed. The child, a male weighing 5lb 5ozs, was severely affected with erythroblastosis and died 2 days later despite 2 exchange transfusions.
In this case the estimates of the biparietal diameter made by ultrasound were small and there was evidence of failure of foetal growth.

foetal head. (Fig. 46).

CASE NO. 2

Mrs. Isabel Brown, aged 29 years, had one child who was born 4 weeks prematurely and weighed 4½ pounds at birth. She was admitted at 30 weeks in her second pregnancy because of slight vaginal bleeding (for which no cause was found) and it was noted that the uterus was only 26 weeks size. As her dates were not in doubt, placental insufficiency was suspected and she was kept in hospital for rest and observation for the remainder of her pregnancy. The patient herself remained perfectly well; she had no further bleeding, was not anaemic and had no signs of toxaemia. Because of the small size of the baby, labour was induced at term and 5½ hours after rupture of the membranes she had a spontaneous vertex delivery of a live female child weighing 3 pounds 9 ounces. The placenta weighed only 10 ounces and was extensively infarcted, only one third of it being functional.

INDICATION FOR CEPHALOMETRY

Uterus small for dates. Probable placental insufficiency.

RESULTS

Eight weekly antenatal measurements suggested that foetal growth was taking place but that the biparietal diameter was much smaller than in normal pregnancy. This was borne out by events. (Fig. 47).

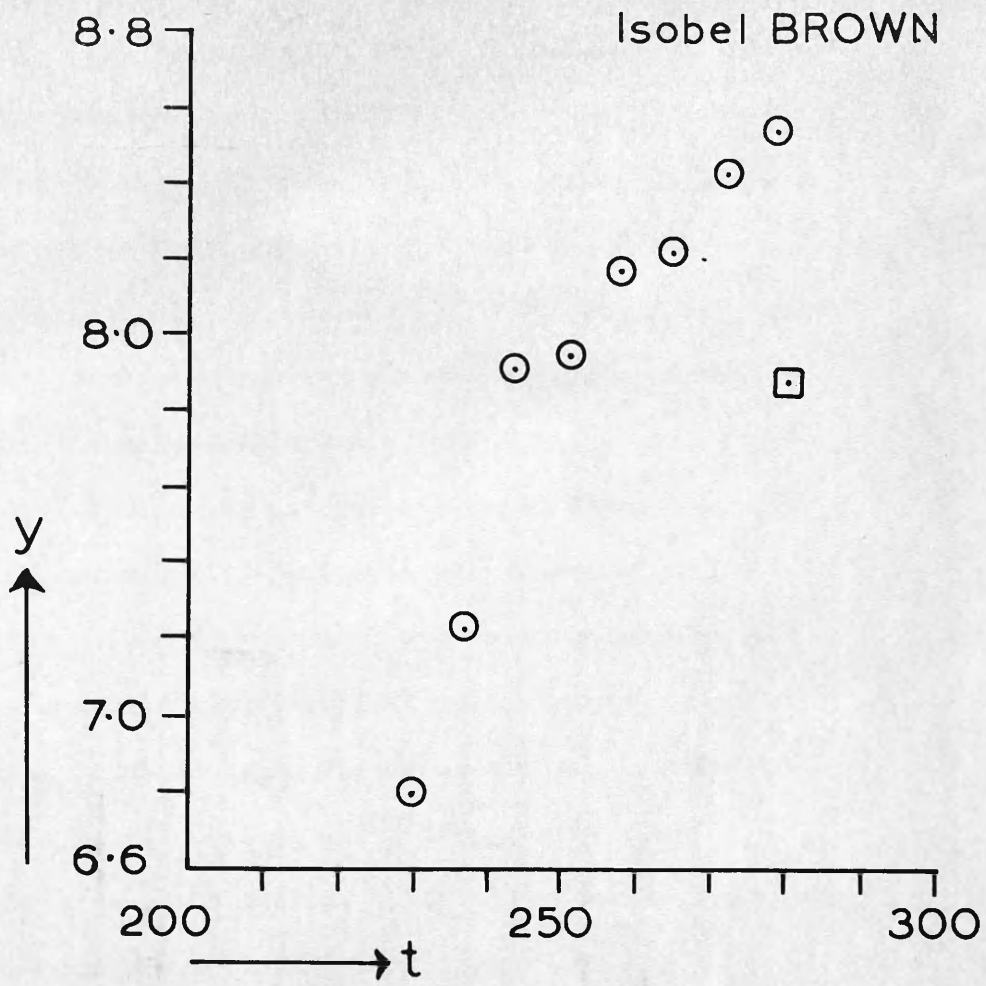


FIG. 47. Placental insufficiency. No evidence of pre-eclampsia. In this case there appeared to be progressive foetal growth but the size of the baby was inadequate as suggested by a biparietal diameter of 8.54 cm. at term.

CASE NO. 3

Mrs. Jane Feeney, aged 22 years, was in her third pregnancy but had no living children. She had first had an abortion at 20 weeks then a premature stillbirth at 32 weeks as the result of concealed accidental haemorrhage. She was admitted at 24 weeks in her third pregnancy with a threatened abortion and it was noted that the uterus was enlarged to the size of a 20 weeks pregnancy only. The patient was in no doubt about her dates. Accordingly, placental insufficiency was suspected. Bleeding settled soon after admission and the patient thereafter remained well, with no signs of toxaemia. Labour began spontaneously at 37 weeks and she had a normal delivery of a live female child weighing 4 pounds 5 ounces. The placenta was infarcted. The baby progressed well.

INDICATION FOR CEPHALOMETRY

Bad obstetric history: small for dates: probable placental insufficiency.

RESULTS

Six measurements obtained antenatally showed appreciable evidence of foetal growth, although the progression was not a steady one, probably due to slight inaccuracies in interpretation. (Fig. 48).

CASE NO. 4

Mrs. Phyllis Nicholls, a primigravida aged 23 years,

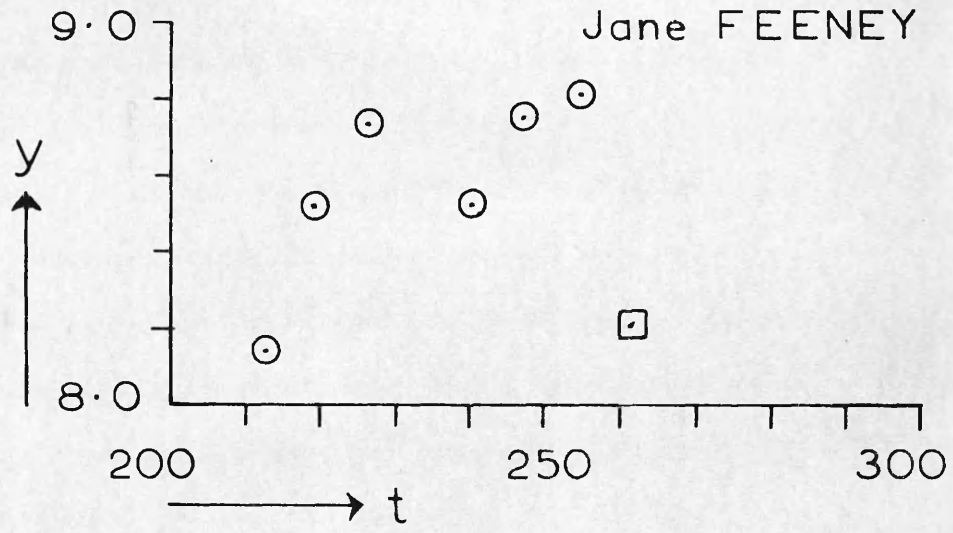


FIG. 48. Placental insufficiency. No evidence of pre-eclampsia. There appears to be a decrease in growth after 32 weeks. The patient had a spontaneous labour at 37 weeks and delivered a baby weighing 4lb 5ozs. The placenta was infarcted.

had a normal blood pressure when she first attended the antenatal clinic. At 28 weeks she developed hypertension and thereafter her blood pressure was high for the rest of her pregnancy, being generally around 140/100 mm. of mercury, the highest level being 155/115 mm. of mercury. There was no oedema or albuminuria. She remained in hospital fromthe 29th week. The baby seemed to be very small and the uterus was at no time more than 28 weeks size. Urinary pregnanediol estimations were made at intervals and these were normal. At 37 weeks, elective Caesarean section was performed and a live female child weighing 3 pounds 8 ounces was extracted. Mother and baby progressed well after delivery.

INDICATION FOR CEPHALOMETRY

Hypertension: small baby: suspected placental insufficiency.

RESULTS

All of the 4 measurements made antenatally were much smaller than normal. Growth was demonstrable but after the 34th week was slight - being only 0.3 cm. in the subsequent 4 weeks. (Fig. 49).

CASE NO. 5

Mrs. Christabel Collins, aged 39 years, gave a history of 6 previous pregnancies, the last 3 of which had been complicated by hypertension. During her last pregnancy she had severe hypertension and had a stillborn

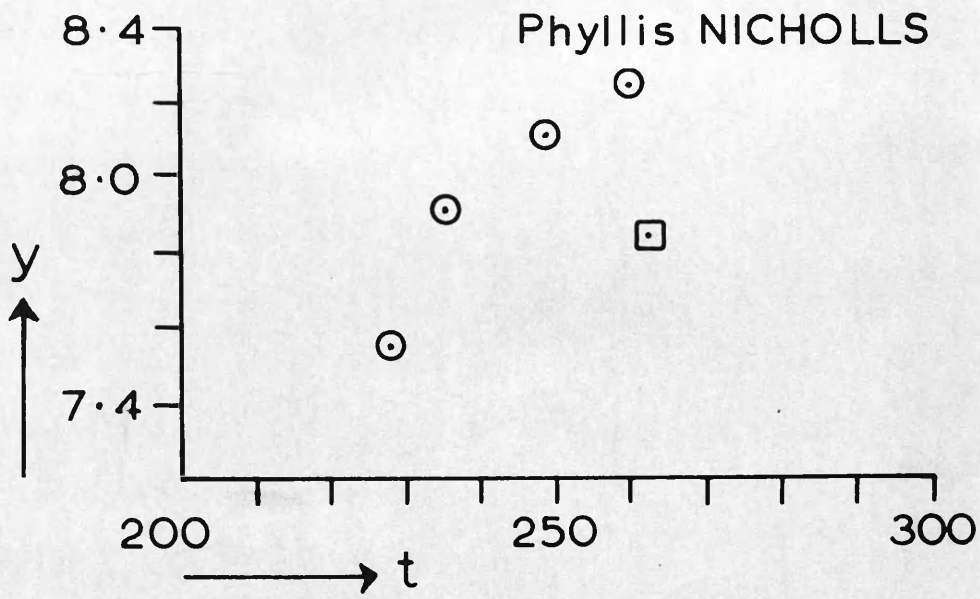


FIG. 49. Hypertensive toxaemia associated with placental insufficiency. Baby was small and uterus did not seem to be growing - it was never more than 28 weeks size. However, cephalometry gave evidence of growth.
Delivery of live child weighing 3½lb by Caesarean section at 37 weeks.

child weighing 3½ pounds at term.

In her 7th pregnancy her blood pressure was very labile, the highest recorded level being 220/130 mm. of mercury and the lowest 110/80 mm. of mercury. A recurrence of placental insufficiency was suspected as the uterus seemed small for the dates. Obesity made it difficult to estimate the size of the baby on palpation. Labour was induced at 38 weeks and she had a spontaneous vertex delivery of a live female child weighing 5 pounds 12 ounces - larger than expected.

INDICATION FOR CEPHALOMETRY

Hypertension: previous placental insufficiency: uterus small for dates.

RESULT

The results obtained indicated that the child was larger than the clinical impression suggested. The calliper measurement made after birth was 0.8 cm. less than the last antenatal ultrasonic measurement, but this was done on the third day when the child had lost oedema. (Fig. 50).

CASE NO. 6

Mrs. Agnes Sharp, aged 33 years, had 2 previous normal pregnancies. She was admitted at 26 weeks in her third pregnancy with premature rupture of the membranes. Despite this, pregnancy continued till 32 weeks although blood stained liquor was draining all the time. The

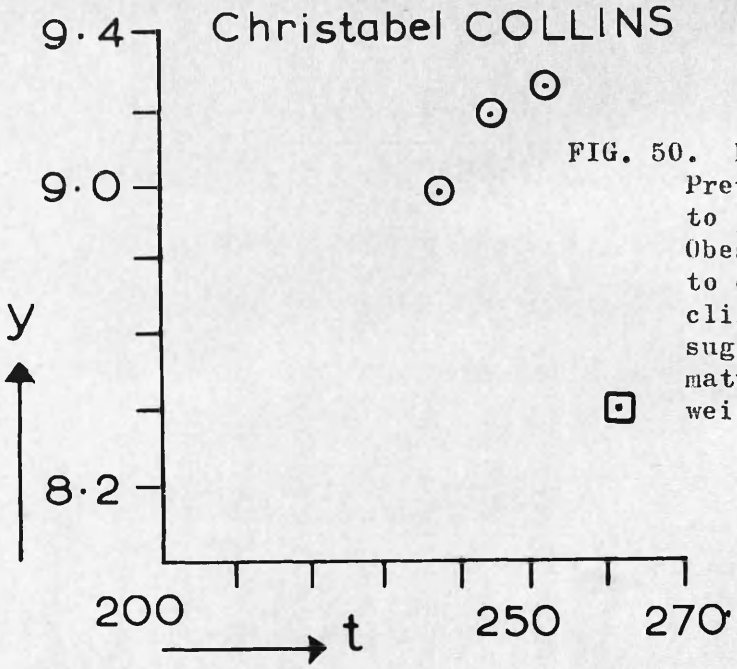


FIG. 50. Hypertension. Previous stillbirth due to placental insufficiency. Obese patient. Difficult to estimate size of baby clinically. Cephalometry suggested that baby was of mature size. Birth weight 5lb 12ozs.

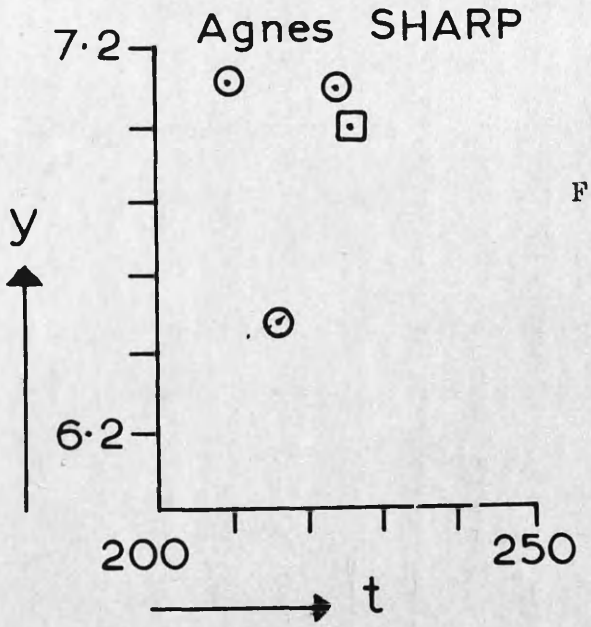


FIG. 51. Premature rupture of membranes at 26 weeks. Pregnancy continued to 32 weeks but uterus did not grow. Very difficult to palpate foetal head and to obtain reliable measurements. Baby weighed 3lb 12ozs and died in 40 hours.

uterus was never more than 26 weeks size and it was suspected that the baby was not growing. Labour began at 32 weeks and lasted off and on for 37 hours, terminating in the spontaneous vertex delivery of a live female child weighing 3 pounds 12 ounces who developed respiratory distress soon after birth and died in 40 hours. The placenta showed a severe degree of circumvallate formation.

INDICATION FOR CEPHALOMETRY

Baby did not seem to be growing. Ruptured membranes made premature labour likely at any time.

RESULT

Due to the absence of an amniotic sac the baby lay bunched up within the uterus and it was difficult to palpate the head. Three ultrasonic measurements were made - in the 30th, 31st and 32nd weeks. The results were rather equivocal although the last ultrasonic measurement agreed well with the calliper measurement made at birth. (Fig. 51).

CASE NO. 7

Mrs. Annie Fordyce, aged 41 years, had marked rickets and severe pelvic contraction. She had a bad obstetric history, having only one live child out of four pregnancies. Her first pregnancy ended in mixed accidental haemorrhage and stillbirth at 32 weeks, her second in the birth of macerated twins at 32 weeks and

her fourth in a stillbirth at 28 weeks. Her surviving child was born at 37 weeks after intrapartum haemorrhage.

In view of her history she was admitted at 32 weeks in her fifth pregnancy. The baby was feared to be very small. At 35 weeks the foetal heart was noted to be slow and irregular and emergency Caesarean section was performed. A live male child weighing 4 pounds 5 ounces was extracted. Mother and baby progressed well.

INDICATION FOR CEPHALOMETRY

Bad obstetric history: suspected placental insufficiency. Premature delivery would almost certainly be necessary if the child's life were to be saved and it was important to try to assess foetal size.

RESULTS

At 33 weeks the foetal biparietal diameter measured 7.5 cm. by ultrasound: at 34 weeks the measurement was 8.5 cm. The calliper measurement at birth 7 days later was 8.4 cm.

CASE NO. 8

Mrs. Jean Cathcart, aged 28 years, had severe pre-eclampsia in her only previous pregnancy and following induction delivered a $3\frac{1}{2}$ pound baby at 34 weeks. The child survived. She was admitted to hospital at 28 weeks in her second pregnancy as she had again developed pre-eclampsia. Her blood pressure was 155/120 mm. of mercury and there was marked albuminuria. The uterus

was small for the dates. Despite treatment her condition did not improve and intra-uterine death occurred in the 32nd week. Three weeks later she had a spontaneous vertex delivery of a macerated male child weighing 2 pounds 6 ounces.

INDICATION FOR CEPHALOMETRY

Severe pre-eclampsia: uterus small for dates.

RESULTS

At 29 weeks the ultrasonic measurement of the biparietal was 6.4 cm.: at 31 weeks it was 7.1 cm. - both measurements being much smaller than normal.

CASE NO. 9

Mrs. Catherine Flavell, a primigravida aged 20 years, was admitted at 32 weeks with severe pre-eclampsia. Her blood pressure was 170/110 mm. of mercury, she was grossly oedematous and there was albuminuria of 1.5 grammes per litre. Her condition did not respond to treatment and at 35 weeks it was decided to terminate the pregnancy. Following induction by rupture of the membranes and oxytocin drip, she was delivered of a live female child weighing 3 pounds 5 ounces. The placenta weighed 12 ounces and was extensively infarcted. The child died 3 days later from septicaemia and pulmonary haemorrhage.

INDICATION FOR CEPHALOMETRY

Severe pre-eclampsia, termination of pregnancy

being considered.

RESULTS

Two clear measurements were obtained, at 33 and 34 weeks: they were both exactly the same (8.4 cm.) reflecting the fact that the baby had stopped growing.

CASE NO. 10

Mrs. Helen Clachan, a primigravida aged 37 years, had chronic nephritis and spent a large part of her pregnancy in hospital - from 22 weeks onwards. Hypertension, albuminuria and oedema were constant features. At 37 weeks she was delivered by Caesarean section of a live male child weighing 3 pounds 14 ounces, who made satisfactory progress.

INDICATION FOR CEPHALOMETRY

Chronic renal disease in pregnancy. Baby was clinically small.

RESULTS

Cephalometry was of no help in this case as the examination was difficult and interpretation of the echoes uncertain. The measurements obtained, 8.6 cm. at 36 weeks and 8.9 cm. at 37 weeks, were not considered reliable.

CASE NO. 11

Mrs. Agnes Mulholland, a primigravida aged 26 years, was admitted to hospital at 38 weeks with a breech presentation. The uterus was only 28 weeks size but the patient was sure of the dates and had been observed at the antenatal clinic since an early stage. The biparietal diameter was estimated by ultrasound at 38 weeks as 7.6 cm.: a week later it was 8.2 cm. Both these estimates were made with the breech presenting.

At term the patient was delivered by elective Caesarean section because of presumed placental insufficiency. The child, a girl, weighed 3 pounds 5 ounces and had a very dehydrated, "post-mature" appearance. There was hardly any liquor amnii. The placenta was infarcted.

The calliper measurement of the biparietal diameter immediately at birth was 8.01 cm.; 24 hours later it was 7.52 cm.

CASE NO. 12

Mrs. Margaret Mead, aged 29 years, had only one living child from 4 previous pregnancies. Intrauterine death had occurred at 36 weeks in her first 2 pregnancies: the third was terminated by elective Caesarean section at 34 weeks but the baby died in the neonatal period: the fourth child was delivered by elective Caesarean section at 32 weeks and survived. This appeared to be a case of

recurrent placental insufficiency.

The patient was admitted in the 32nd week of her fifth pregnancy because of mild hypertension - a feature which had not been present in her previous pregnancies. The uterus was small for the dates.

The biparietal diameter was estimated on admission as 8.0 cm.; 5 days later it was 8.08 cm. On the day after the last estimate - at 32 weeks gestation - Caesarean section was performed and a female child weighing 3 pounds 2 ounces was delivered. The placenta weighed only 9 ounces and was extensively infarcted. The baby died 4 days after birth.

CASE NO. 13

Mrs. Christine McInnes, aged 30 years, had one living child, from her second pregnancy. All her other pregnancies had ended in miscarriage in the third month. In her eighth pregnancy, Shirodkar's operation of cervical suture was performed at 10 weeks. In the later weeks of pregnancy it was thought that the uterus was small and it was feared that placental insufficiency might be playing a part.

The biparietal diameter was estimated by ultrasound 10 days before term as 8.77 cm. Six days later the patient had a spontaneous vertex delivery of a live child weighing 5 pounds 3 ounces. The calliper measurement one hour after birth was 8.59 cm.

In this case ultrasonic cephalometry suggested that the baby was not so small as the clinician feared, and this was proved to be the case. The child subsequently did well.

GROUP 9

DIABETES MELLITUS

In recent years, the foetal mortality in cases of diabetes has been reduced by recognition of the fact that strict control of maternal diabetes combined with delivery of the baby around the 36th week reduces the foetal loss due to intra-uterine death in the later weeks of pregnancy and in labour, and neonatal death.

It has long been recognised that the babies of diabetic mothers tend to be very large for the period of gestation and in the past they have often been wrongly classed as post-mature. OAKLEY and PEEL (1949) stated that 45 per cent of the babies in their series were over 7 pounds in weight at 36 weeks in cases where there was no hydramnios: where hydramnios was present, 70 per cent were over that weight. These babies are uniformly overgrown, although part of their excessive weight is due to oedema of the skin and subcutaneous tissues and they behave and must be treated as premature, no matter how large they are.

It was thought interesting to apply the method of biparietal cephalometry to a series of these cases in an attempt to assess the growth of the foetus and to try to predict whether the foetus would be unduly large or not.

CASE NO. 1

Mrs. Norma Macmillan, a primigravida aged 21 years, was admitted to hospital at 30 weeks because her insulin dosage required stabilisation. She was discharged after 2 weeks and continued to attend as an out-patient. She was re-admitted at 36 weeks and labour was induced by puncture of the membranes followed by an oxytocin drip. She had an easy mid forceps delivery of a live female child weighing 5 pounds 10 ounces. Mother and child progressed well during the puerperium.

RESULTS

Measurements of the biparietal diameter were made at weekly intervals from the 30th to 36th week. These confirmed normal foetal growth. The patient had no other complications such as hydramnios or pre-eclampsia and her diabetes was quite stable apart from the initial period when her insulin dosage required adjustment. This favourable state of affairs is probably reflected in the fact that the baby did not grow excessively, was not oedematous at birth and had no complications in the neonatal period. (Fig. 52).

CASE NO. 2

Mrs. Elizabeth Friel, aged 27 years, had two previous pregnancies. Her first child was born prematurely at 34 weeks and weighed $4\frac{3}{4}$ pounds. Her second child, at term, weighed $7\frac{1}{2}$ pounds. After her

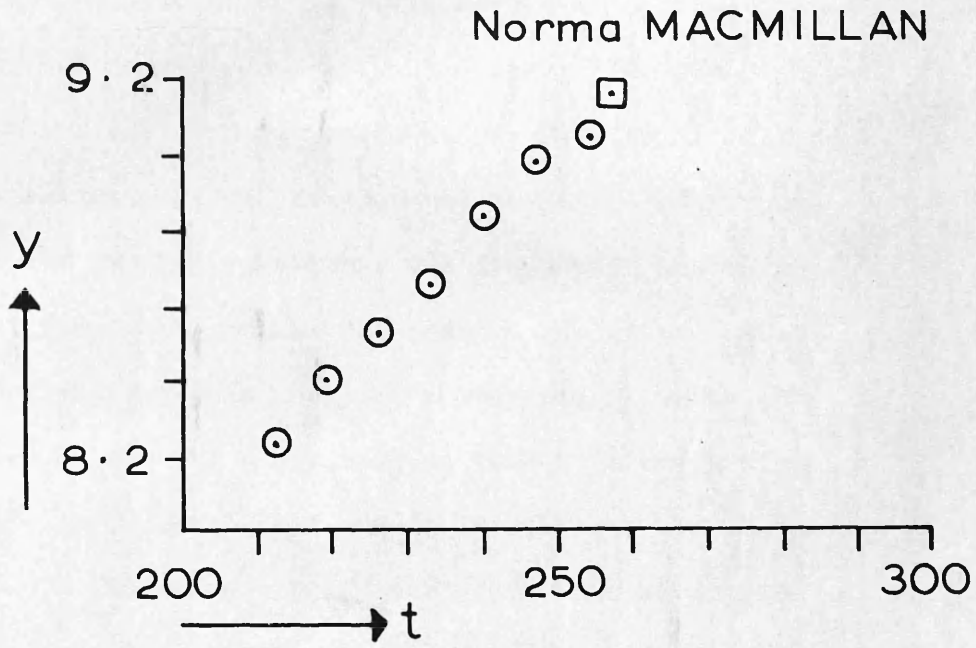


FIG. 52. Primigravida with well controlled diabetes. Progressive steady growth demonstrated by cephalometry, which also suggested that the foetus was not of excessive size for the duration of pregnancy. The patient had a vaginal delivery of a 5lb 10oz baby following induction at 36 weeks.

second pregnancy, she was found to have diabetes. She was admitted to hospital supposedly at 36 weeks, but the uterus was smaller than the dates suggested and the radiological maturity was only 32 weeks. The biparietal diameter was measured by ultrasound at 8.46 cm. In view of this evidence it was decided not to induce labour but to wait for another 4 weeks as the dates were probably wrong. Therefore, labour was induced (by rupture of the membranes and oxytocin drip) at a probable 37 weeks gestation. She had a spontaneous vertex delivery of a live male child weighing 6 pounds 12 ounces 6 hours after induction. The baby showed none of the characteristic features associated with maternal diabetes and progressed well.

RESULTS

Here again well controlled maternal diabetes in pregnancy resulted in the delivery of a baby of normal weight. This was in accordance with the findings suggested by ultrasonic cephalometry. Four antenatal measurements showed progressive growth to a diameter of 9.2 cm. before term. (Fig. 53).

CASE NO. 3 (a)

Mrs. Doreen McCabe, aged 26 years, was in her second pregnancy. She had had diabetes for 5 years and her last baby had been delivered by Caesarean section at 36 weeks, and weighed 8 pounds at birth. During her second

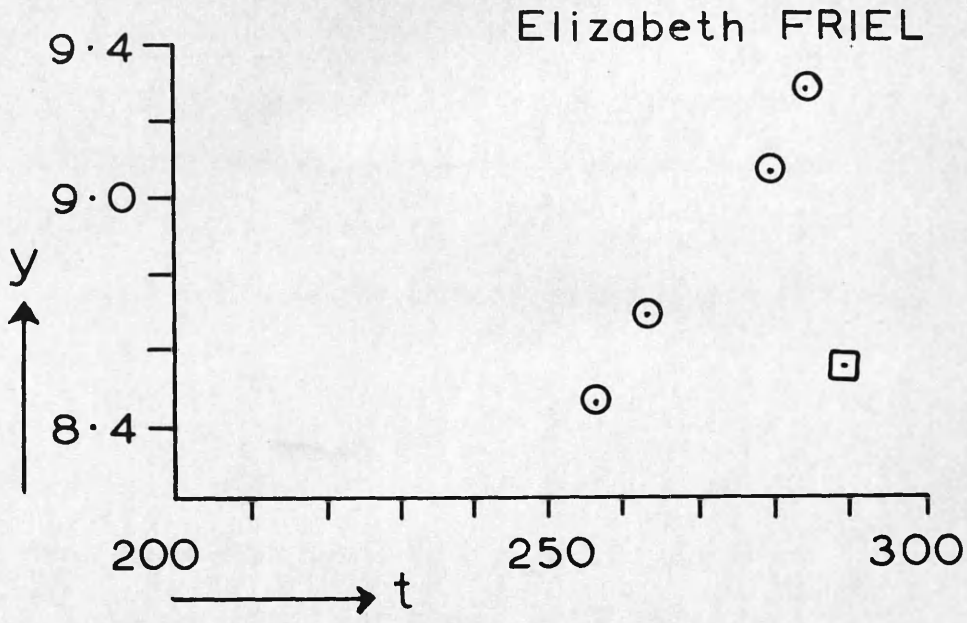


FIG. 53. Diabetes. Doubtful dates. Foetal cephalometry by ultrasound suggested that the expected date might be four weeks later than calculated. X-ray maturity was in agreement with this. Fairly rapid growth is demonstrated here. Induction of labour was performed when the baby was probably 37 weeks mature. There was a spontaneous delivery of a child weighing 6lb 12ozs.

pregnancy she remained fairly well, although she was obese and required alterations in her insulin dosage as pregnancy progressed. In the 37th week she was delivered by repeat Caesarean Section of a live female child weighing 8 pounds. The baby was oedematous and presented the typical "diabetic" appearance. The baby lost 11 ounces weight in the first 3 days and thereafter progressed well.

RESULTS

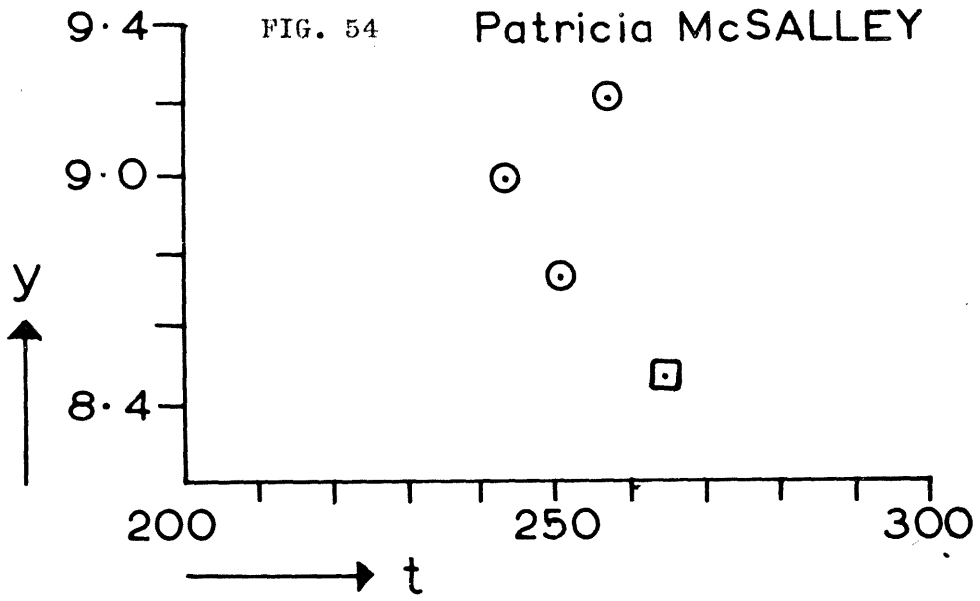
The 3 measurements of the biparietal made before birth were larger than would be expected in the normal case. The biparietal after birth - as measured by calliper - decreased by 0.7 cm. in the first 3 days of life. (Fig. 55).

CASE NO. 3 (b)

Mrs. McCabe was re-admitted at 36 weeks in her third pregnancy, less than 11 months after the birth of the baby described above. The biparietal, measured by ultrasound, was 9.1 cm. The day after this measurement was made, she was delivered by Caesarean section of a live female child weighing 6 pounds 15 ounces. The calliper measurement of the biparietal 5 hours after birth was 8.8 cm.

CASE NO. 4

Mrs. Patricia McSalley, aged 27 years, had one previous miscarriage but no living children. She was



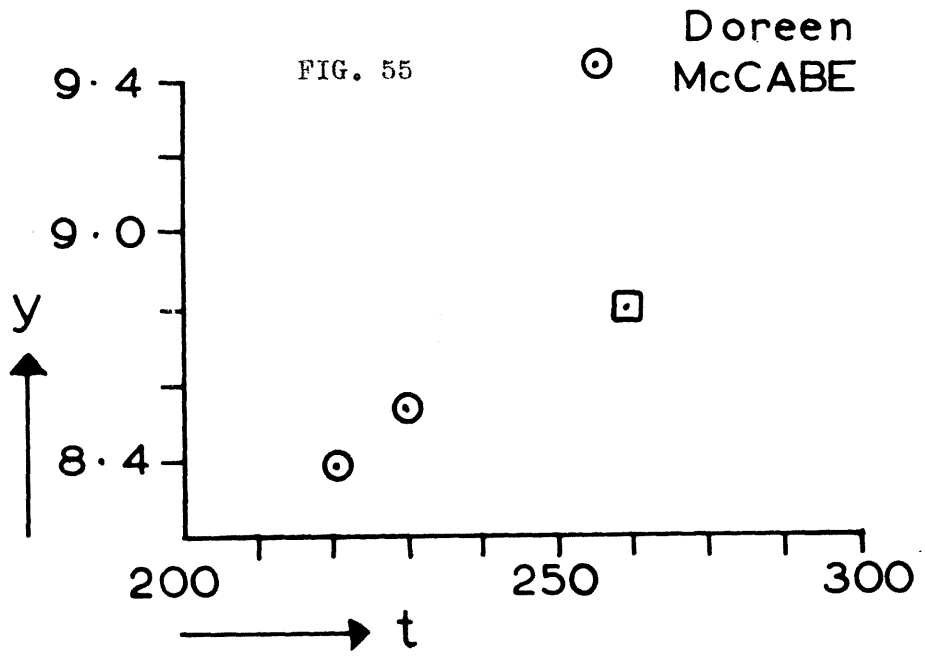


FIG. 54. Diabetes. Difficult case to examine. The second result is not in agreement with the other two antenatal estimates.

FIG. 55. Diabetes. Estimates of biparietal diameter by ultrasound are larger than normal. 8lb baby delivered by Caesarean section at 37 weeks.

first admitted in her second pregnancy at 20 weeks because of threatened miscarriage. This settled with rest, but her diabetes was very unstable. She was slightly hypertensive and required constant supervision. Accordingly, most of the rest of her pregnancy was spent in hospital. In the 37th week she was delivered by Caesarean section of a live male child weighing 6 pounds 9 ounces.

RESULTS

This was not an easy case to examine as the echo pattern was not clear. The 3 measurements obtained antenatally were roughly consistent with the baby's eventual size. (Fig. 54).

CASE NO. 5

Mrs. Elizabeth Sinnott, aged 36 years, had had both her previous deliveries by Caesarean section on account of diabetes. Her first child, at term, weighed 11 pounds, her second, at 38 weeks, weighed 12 pounds. In her third pregnancy she was delivered by Caesarean section at 37 weeks of a live male child weighing 8 pounds 13 ounces.

RESULTS

Three measurements between the 35th and 37th weeks suggested that the foetal head was of moderate size. The biparietal diameter decreased in the first 4 days of life by nearly 0.8 cm. (Fig. 56).

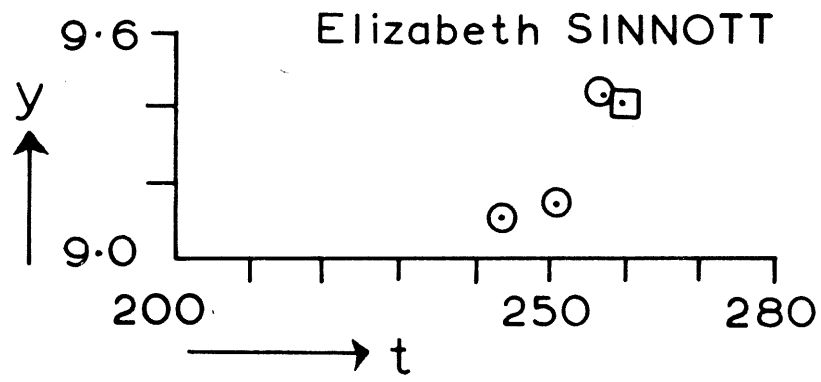


FIG. 56. Diabetes. Two previous big babies (11 lb and 12 lb). Antenatal estimates of the biparietal diameter in her third pregnancy suggested that the foetal head was of moderate size only. She was delivered by Caesarean section at 37 weeks. The baby weighed 8lb 13ozs.

CASE NO. 6

Mrs. Janet McLaggan, aged 35 years, had had 2 previous Caesarean sections at 36 weeks because of diabetes: the babies weighed 10 pounds and 6 pounds 11 ounces respectively. She was well and her diabetes fairly stable during her third pregnancy. At 37 weeks she was delivered by Caesarean section of a live male child weighing 7 pounds 2 ounces.

RESULTS

Two measurements - in the 36th and 37th weeks - were almost the same, being 8.92 cm. and 9.01 cm. This indicated that the baby was probably not very large. No measurement was made in the neonatal period until the 7th day, when the biparietal was 8.51 cm. by ultrasound and 8.54 cm. by calliper.

CASE NO. 7

Mrs. Morag Castel, aged 32 years, had been delivered by Caesarean section in her only previous pregnancy because of diabetes: the operation was performed at 34 weeks and the baby weighed 8 pounds 10 ounces. In her second pregnancy, labour was induced at 35 weeks and she had a forceps delivery of a girl weighing 8 pounds 11 ounces.

RESULT

Only one measurement was made antenatally - at 30 weeks. The estimate of the biparietal was then

8.23 cm. - a little larger than is generally found at that stage.

The calliper measurement 7 hours after birth (5 weeks after the ultrasonic measurement) was 9.14 cm.

CASE NO. 8

Mrs. Maureen Finnie, aged 36 years, was in her 4th pregnancy. Her first two pregnancies had occurred just before she became diabetic: the first baby weighed 5 pounds 11 ounces when born at 38 weeks, the second 9 pounds 12 ounces at 37 weeks, probably indicating a pre-diabetic state. In her third pregnancy she had labour induced at 34 weeks because of diabetes: the baby weighed 6 pounds 11 ounces.

During her 4th pregnancy she was well and her diabetes was stable. Labour was induced at 36 weeks and she had a spontaneous vertex delivery of a live male child weighing 8 pounds.

RESULT

An ultrasonic measurement was made 2 days before delivery and was 9.49 cm. The calliper measurement 2 days after delivery was 9.1 cm.

GROUP 10

MALPRESENTATIONS AND VARIABLE LIE OF THE FOETUS

In these cases the clinical problem to which cephalometry was applied was to estimate the size of the foetal head where there was an actual or likely malpresentation. As has been pointed out, radiology is very unreliable in these circumstances.

Some patients included in this series are examples of those in which the presenting part could not be determined on palpation, either due to obesity, tight abdominal muscles or some other cause, and the clinician in charge of the case requested ultrasonic examination as a quick way of determining the situation of the foetal head. The method has been used quite widely for this purpose although only a few cases are recorded here. Little more need be said about this simple diagnostic use of ultrasonic cephalometry except to emphasise the difficulties which may be encountered in cases of multiple pregnancy, as is mentioned in the section on that subject.

Returning to the clinical problem of malpresentations and variable lie, the question which the obstetrician must often ask when dealing with such cases is "Is it saft to attempt vaginal delivery in this patient"?. The answer to this question often depends on the size of the baby, and information about the size of the foetal head

is helpful. It is considered dangerous by most obstetricians to attempt vaginal delivery in a case of breech presentation where there is any suspicion of pelvic contraction. It may similarly be dangerous to allow a patient in whom the lie of the foetus is unstable to go into labour if the child is very large.

Measurement of the foetal head, of course, provides information about only one facet of the problem, but the more that is known about all aspects of the case before labour starts the more satisfactory the outcome is likely to be. The foetal mortality associated with malpresentations and variable lie is still too high and anything that will help in assessment of these problems is to be welcomed.

CASE NO. 1

Mrs. Agnes Clarke, aged 28 years, had 2 previous babies who both weighed $8\frac{3}{4}$ pounds at birth. In the last 7 weeks of her third pregnancy the lie of the foetus was unstable, being sometimes breech, sometimes transverse but generally oblique. The baby was thought to be large. In the 42nd week, labour began spontaneously and, with uterine contractions, the presentation became vertex. After 9 hours she had a spontaneous vertex delivery of a live male child weighing 10 pounds 14 ounces.

INDICATION FOR CEPHALOMETRY

Unstable lie. Big baby.

RESULTS

Foetal growth was followed in this case from the 34th to 42nd week. Despite the eventual large weight of the baby, the biparietal diameter did not appear to grow to an excessive size. (Fig. 57).

CASE NO. 2

Mrs. Helen Adam, a primigravida aged 26 years, was just under 5 feet in height. At 36 weeks she was found to have a breech presentation. External cephalic version was attempted under anaesthesia without success. On vaginal examination there was no obvious pelvic contraction.

At 38 weeks she developed slight hypertension and

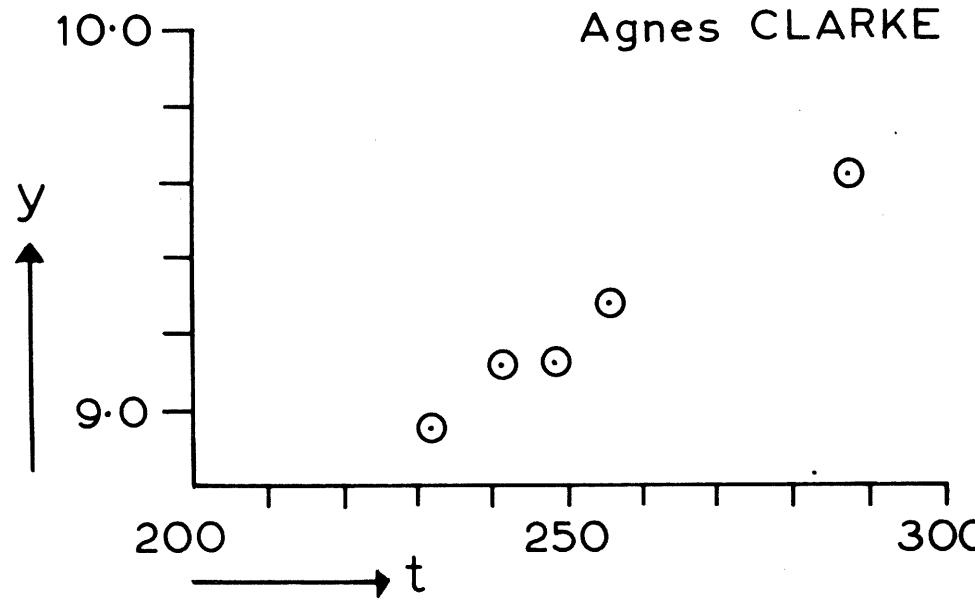


FIG. 57. Unstable lie. Child seemed large on palpation. The patient had an easy delivery of a 10lb 14oz baby. Despite the heavy weight of the child the biparietal diameter did not grow to an excessive size.

was admitted to hospital. Labour was induced 9 days before term and she had an assisted breech delivery of a live male child weighing 6 pounds 9 ounces.

INDICATION FOR CEPHALOMETRY

Persistent breech presentation in a primigravid patient who was less than 5 feet in height.

RESULTS

Measurements were made from the 36th to the 39th week and showed an increase of 0.5 cm. in the biparietal during that time. There was nothing to suggest excessive size of the foetal head. (Fig. 58).

CASE NO. 3

Mrs. Margaret Barbour, aged 40 years, had one child born at 34 weeks because of anaemia and in the later weeks of pregnancy developed an unstable lie. The foetal biparietal diameter was estimated at 35 weeks, when it was 9.72 cm. and at 38 weeks, when it was 10.25 cm. These measurements were made with the vertex presenting, but the presentation was very unstable. At term she was delivered by elective Caesarean section of a live child weighing $8\frac{1}{2}$ pounds. The calliper measurement of the biparietal on the 7th day of life was 9.70 cm.

CASE NO. 4

Mrs. Flora Cameron, aged 40 years, was admitted at

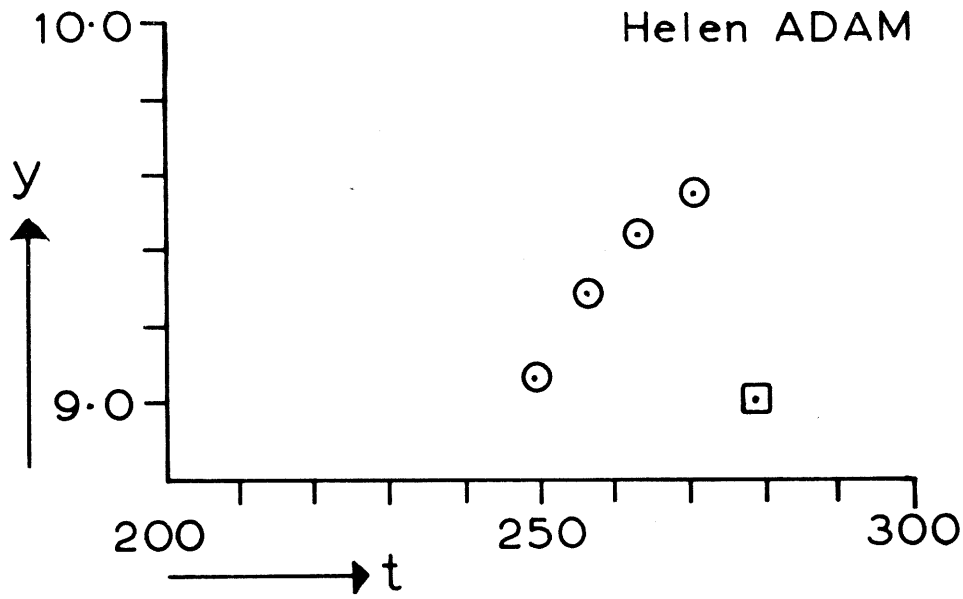


FIG. 58. Primigravida. Breech presentation. Progressive increase in the biparietal diameter is demonstrated, but the measurements are not unduly large. The patient had an assisted breech delivery of a baby weighing 6lb 9ozs.

term in her 4th pregnancy because of variable lie. There was slight hydramnios and the foetus was very mobile. Two estimates were made of the biparietal with an interval of 4 days between them: the first was 9.79 cm., the second 9.85 cm.: the lie was transverse on both occasions. Five days after term (2 days after the last measurement) the patient was delivered by Caesarean section of a baby girl weighing 7 pounds 3 ounces. The external calliper measurement 24 hours after birth was 9.52 cm.

CASE NO. 5

Mrs. Agnes Scott, aged 37 years, had 3 previous normal pregnancies. She was admitted to hospital 10 days before her expected date in her 4th pregnancy as she had been found to have a breech presentation. External cephalic version was attempted and it was thought that it was successful, but ultrasonic examination showed the foetal head to be at the fundus: the biparietal diameter was estimated at 8.71 cm. A week later the estimate was 8.86 cm. On the day following this examination the membranes were artifically ruptured to induce labour, but the cord prolapsed and Caesarean section was immediately performed. The child, a girl, weighed $6\frac{1}{2}$ pounds. The external calliper measurement 24 hours after birth was 8.64 cm.

CASE NO. 6

Mrs. Elizabeth Scott, aged 41 years, had 4 previous babies who weighed between 8½ and 10 pounds at birth. She was admitted at 38 weeks in her 5th pregnancy with a breech presentation. External version was unsuccessful. The ultrasonic estimate of the biparietal diameter on admission was 9.62 cm.; a week later it was 9.79 cm. On the day following the last measurement the patient was delivered by Caesarean section of a live female child weighing 8 pounds 13 ounces. The calliper measurement made immediately at birth was 9.92 cm.; 24 hours later it had decreased to 9.30 cm.

CASE NO. 7

Mrs. Sarah Carruthers, a primigravida aged 35 years, was admitted to hospital at 37 weeks because of mild pre-eclampsia. During her stay in the antenatal ward the lie of the foetus was constantly oblique, with the head in the right iliac fossa. An ultrasonic estimate of the biparietal diameter in the 39th week was 9.7 cm. Five days later she was delivered by Caesarean section. The child, a girl, weighed 7 pounds 12 ounces. A calliper measurement on the 6th day was 9.2 cm.

CASE NO. 8

Mrs. Annie Keane, aged 36 years, had 2 previous large babies and had had a Caesarean section for placenta

praevia. The breech was found to be presenting at 37 weeks and the ultrasonic estimate of the biparietal was 10.13 cm., suggesting that the baby was big. Five days later she was delivered by Caesarean section of a boy weighing 9 pounds. The calliper measurement on the 3rd day of life was 9.65 cm.

CASE NO. 9

Mrs. Elizabeth Kilcullen had 3 children who weighed between 8 and 9 pounds at birth. She was admitted at term in her 4th pregnancy on account of variable lie. Ultrasonic examination on admission estimated the biparietal diameter at 9.43 cm. Two days later she went into labour with the vertex presenting and had a spontaneous delivery of a boy weighing 7 pounds 6 ounces. The calliper measurement of the biparietal diameter 24 hours after birth was 9.40 cm.

CASE NO. 10

Mrs. Margaret McAuley, aged 25 years, had 2 previous big babies - 9½ and 10 pounds at birth. She was admitted at 37 weeks in her third pregnancy because of variable lie. Despite repeated external version in hospital, transverse lie constantly recurred. The ultrasonic estimate of the biparietal diameter 3 days past term was 10.65 cm., the measurement being made with the foetus as a transverse lie. The measurement

suggested that the baby was big. On the same day the patient was taken to theatre for examination under anaesthesia with a view to external version and artificial rupture of the membranes. When she was placed on the theatre table the membranes ruptured spontaneously and much heavily meconium stained liquor was discharged. Caesarean section was therefore performed and a live female child weighing 9½ pounds was extracted. The biparietal diameter measured by calliper 6 hours after delivery was 9.95 cm.

CASE NO. 11

Mrs. Mary McKinley, aged 27 years, who had had one baby who weighed 7 pounds at birth, was admitted at term because of variable lie. After 3 days in hospital the presentation settled to vertex. An ultrasonic estimate of the biparietal at 41 weeks was 10.2 cm., suggesting a big baby. Two days later she had a spontaneous vertex delivery of a baby boy weighing 9 pounds 10 ounces. The external calliper measurement on the second day of life was 9.53 cm.

CASE NO. 12

Mrs. Roberta McLellan, a primigravida aged 24 years, was admitted at 37 weeks with slight hypertension. The breech was suspected to be presenting but abdominal palpation was difficult as the muscles were tense.

Ultrasonic examination confirmed the presence of the foetal head at the fundus uteri and estimated the biparietal diameter at 9.34 cm. Six days later, following surgical induction, she had an assisted breech delivery of a girl weighing 6 pounds 10 ounces. No calliper measurement was obtained.

CASE NO. 13

Mrs. Mary McMaster, a primigravida aged 35 years, was found to have a breech presentation at term. At 41 weeks the ultrasonic estimate of the biparietal diameter was 9.69 cm. The next day the patient was delivered by Caesarean section of a girl weighing 7 pounds 4 ounces. The calliper measurement after birth was 9.1 cm.

GROUP 11

MULTIPLE PREGNANCY

Although the presence of more than one foetal head can often be demonstrated by finding the typical A-scope pattern at more than one place in the pregnant uterus, the method is not a very reliable one for the diagnosis of multiple pregnancy, being inferior both to conventional radiology and to the "compound sector scanning" ultrasonic method which has been applied extensively by DONALD et al. (1958) in gynaecological patients. For example, in the first case recorded in this group, one of triplets, echoes were obtained from only two of the foetal heads, the third being inaccessible both to palpation and ultrasonic scanning, although it was, of course, clearly seen on x-ray. The reason for this is that the ultrasonic beam encounters multiple reflecting surfaces - principally foetal limbs - which are liable to confuse the picture. Similarly, because of the difficulty in obtaining clear and reliable echoes from the foetal head, it is difficult to follow foetal growth by repeated measurements in these cases. From time to time, however, a suitable case may be encountered in which ultrasonic cephalometry can give useful information about foetal size, maturity and growth.

CASE NO. 1

Mrs. Henrietta Sanderson, a primigravida aged 37 years, was found to have triplets. Ultrasonic examination was first performed at 33 weeks, was repeated at 34 weeks and again at 38 weeks. On all these occasions echoes were obtained from the heads of the first child, presenting by the vertex and fairly easily palpable, and the third child, a breech presentation with the head not clearly palpable. Echoes were never seen from the head of the second child, which was obscured behind the bodies of the other two.

The results were as follows:-

	Triplet 1 (Vertex)	Triplet 3 (Breech)
At 33 weeks	8.95 cm.	8.15 cm.
At 34 weeks	8.37 cm.	8.34 cm.
At 38 weeks	9.79 cm.	7.96 cm.

The echo pattern obtained on the last examination was the clearest and indicated that the first child was considerably larger than the third, thus being in agreement with the measurements obtained on the first examination. The pictures obtained on the second examination were indefinite and the results were considered unreliable.

Caesarean section was performed 10 days before term and 4 days after the last examination. All three babies were lively: the first, a girl, weighed 5½ pounds, the second, a boy, weighed 4 pounds 12 ounces, the third, a

FIG. 59. X-ray of triplets showing how second head was inaccessible to ultrasonic examination.

girl, weighed 3 pounds 13 ounces.

Calliper measurements of the biparietal diameter were made in all three as follows:-

	Triplet 1	Triplet 2	Triplet 3
Within 1 hour of birth	9.91 cm.	8.27 cm.	8.77 cm.
At 24 hours	9.72 cm.	8.13 cm.	8.20 cm.

Thus the last ultrasonic prediction of the biparietal measurement of the first child appeared to be accurate: the prediction in the case of the third was only approximate. In all three, the biparietal diameters decreased during the first 24 hours of life.

Mrs. Sanderson made an uneventful recovery and all the babies did well. (Fig. 59)

CASE NO. 2

Mrs. Margaret Durie, aged 24 years, had one previous child who weighed 9 pounds 5 ounces at birth. In her second pregnancy, she attended the antenatal clinic for the first time when 39 weeks pregnant and was found to have twins. She was admitted to hospital. Labour did not ensue on the expected date.

Ultrasonic examination was first performed 3 days after term. The first twin presented by the vertex, the second by the breech. The measurements obtained were 9.39 cm. and 9.0 cm. respectively. The examination was repeated 6 days later: the measurement from the first twin was 9.44 cm. but no clear echoes could be

obtained from the second head.

At 42 weeks (4 days after the second examination) labour was induced and the patient was delivered of twin girls weighing 6 pounds 9 ounces and 6 pounds 3 ounces. The calliper measurements 24 hours after birth were 8.9 cm. and 8.8 cm. respectively.

In this case, ultrasonic cephalometry helped to confirm the presence of twins of mature size.

CASE NO. 3

Mrs. Annie Heaney, aged 43 years, had 4 previous normal deliveries. She was admitted at 33 weeks in her 5th pregnancy with slight vaginal bleeding and was found to have twins. Placentography and speculum examination were negative. Ultrasonic examination on 2 occasions during the 34th week made the same estimate of the biparietal diameter, viz. 9.28 cm. and 8.90 cm.

The patient was discharged and re-admitted in labour at 38 weeks. She had a spontaneous delivery. The first twin, a girl weighed 5½ pounds, the second, a boy, weighed 5 pounds 11 ounces.

GROUP 12

FOETAL ABNORMALITY

Two of the most common foetal abnormalities are anencephaly and hydrocephaly. Ultrasonic cephalometry can demonstrate both these conditions, although at the present stage of development it cannot provide a reliable means of diagnosis. Anencephaly may be suspected if the characteristic head echoes are not seen and hydrocephaly may give an abnormally large biparietal diameter, but in both conditions an x-ray offers a much more certain means of diagnosis. Doubtful findings on ultrasonic examination may suggest that it would be worthwhile to take an x-ray although radiology is not infallible in cases of hydrocephaly.

CASE NO. 1

Mrs. Cuddihy, a primigravida aged 40 years, went into labour prematurely at 34 weeks. The presenting part could not be clearly felt on palpation. Ultrasonic examination showed clear head echoes at the fundus, suggesting breech presentation, but it was noted that the measurement of the biparietal was abnormally large - 11.8 cm.

X-ray confirmed breech presentation and the appearance of the head was suggestive, although not diagnostic of hydrocephalus. At delivery (which was by manual breech extraction the foetus was found to have a spina bifida and meningocoele, through which a large quantity of cerebrospinal fluid was drained, resulting in collapse of the hydrocephalic head. The foetus weighed 5 pounds.

CASE NO. 2

Mrs. Margaret King, aged 33 years, was found, in her 3rd pregnancy, to have multiple congenital foetal abnormalities including hydrocephaly diagnosed by x-ray at 34 weeks. An ultrasonic estimate of the biparietal diameter at this stage was just under 9 cms. which seemed curious in view of the report of hydrocephaly. However, on reviewing the films the head was found to be markedly elongated, and it is quite possible that the biparietal diameter was not more than normal. At term the patient had a breech delivery with decompression of the hydrocephalic head by draining the cerebrospinal fluid

through the myelocoele which was present. The stillborn child weighed $5\frac{1}{2}$ pounds.

CASE NO. 3

Mrs. McSwiggan, a primigravida aged 20 years, was found to have a breech presentation. External cephalic version failed and x-ray showed appearances suggestive of hydrocephalus. The ultrasonic estimate of the biparietal diameter was 10.5 cm., which seemed unduly large. The patient was delivered by manual breech extraction with collapse of the hydrocephalic head.

DISCUSSION

> "A premature desire to generalize, an eagerness to arrive at conclusions, and a readiness to rest in them, are very common infirmities, and they offer very serious hindrances to the right acquisition of facts".
>
> PETER MERE LATHAM.

The author has attempted to avoid these "common infirmities" and views the work which has been described, although extending over three years, as being of a preliminary nature.

A new method of measuring an important diameter of the foetal head in utero has been established. This was the original purpose of the research.

The method has been applied in a wide variety of patients in a busy maternity unit which deals with many abnormal cases. The results are comparable with the best results of cephalometry by x-rays and the ultrasonic method has the great advantage that, whereas it is inadvisable to repeat x-ray cephalometry frequently, cephalometry by ultrasound can be repeated as often as necessary to show growth of the foetal biparietal diameter.

It is clear that the method is of considerable value in the study of foetal growth. Although the number of cases in which a large enough series of measurements has been made is still too small for a statistical analysis to yield valuable results, the measurements have a high

degree of reproducibility and the work already done paves the way for further study of the growth of the foetal head. It is now apparent that an extensive investigation would be well worthwhile. Ideally this should be carried out by workers in as many different centres as possible. The ultimate interest and value of the work is likely to lie in such abnormalities as have been illustrated in the case reports but, of course, for statistical purposes a large number of normal cases would be desirable. Many interesting relationships are likely to exist between the foetal biparietal diameter and such maternal parameters as height, weight, parity, weights of previous babies, blood pressure, haematological and urinary findings and perhaps also exfoliative vaginal cytology; accumulation of more data will enable these relationships to be worked out in detail. An increase in the number of observations will increase the precision of any comparisons and will enable general conclusions to be drawn.

As applied to individual cases, the results have been of great interest and, in some of the cases which have been described, cephalometry by ultrasound gave information which could not be obtained in any other way.

The work has been done by an obstetrician and a physicist using equipment supplied by a large industrial firm with an active interest in research. Team work of this kind is likely to benefit clinical obstetrics in

many ways and it is interesting to note that the Americal Gynaecological Society has recently produced a report which stresses how important it is that basic scientists should work in a clinical department of obstetrics and gynaecology, as clinicians are unable to cope with the technical problems involved in modern research (TAYLOR, 1962). In the work on foetal cephalometry by ultrasound an attempt has been made to bring research literally to the bedside. There is no branch of medicine in which day-to-day (and sometimes minute-to-minute) observation of the patient is more valuable than in obstetrics and, in addition to general studies on foetal growth along the lines already suggested, more frequent observations on the same patient may give valuable information - especially around the time of delivery. On the purely scientific side, what is needed most is research on the propagation of ultrasound in living tissues[+] - more study of the speed of ultrasound in various tissues and investigation of the meaning of the varying amplitude of echoes obtained from tissue interfaces.

[+] It has been observed by many workers that ultrasound does not produce the same effects in the cadaver as in the living body. The author experimented with ultrasonic cephalometry on a dead foetus and was unable to derive any valid information from this.

Ultrasound at the power levels used for diagnosis appears to be safe. GORDON (1963) points out that the belated discovery that x-rays had deleterious incidental effects has not been repeated in the field of ultrasound. He adds that very little has been published directly on the risks involved in diagnostic techniques because nobody has been able to produce demonstrable lesions by means of brief pulses followed by relatively much longer periods of rest. Continuing, GORDON states, "The writer, taking extrapolations from the work of FRY to the conditions obtaining in the foetal brain when examined by DONALD'S technique, computed that the factor of safety was of the order of 10^5 to 10^6. Such extreme extrapolations are of very questionable value in absolute terms, but they suffice to show that the risks of any pulse technique compare favourably with most other special investigations".

A safe diagnostic method complementary to x-rays is particularly welcome in pregnancy, as the harmful effects of x-rays have been subject to a great deal of discussion since STEWART et al. (1956) first suggested an association between diagnostic radiation in utero and an increased incidence of malignancy, including leukaemia, in children. A recent editorial in "The Lancet" (1963) reviews eleven reports, some conflicting, which have appeared on this subject since 1956 and states that the evidence is now good enough to accept that irradiation in utero is

associated with an increased incidence, although relatively small, of cancer and leukaemia in childhood. There is, therefore, in view of the risks of x-rays, all the more need to develop ultrasonic techniques for use in pregnancy.

Foetal cephalometry by ultrasound has wide applications and, although occasionally the results may be so difficult to interpret as to be unreliable, it is possible to obtain a measurement in nearly every case examined from the 26th to 28th week of pregnancy onwards.

The uses of the "A-scope" type of ultrasonic echo display for medical diagnosis must necessarily be limited, for, where detailed information is desired about internal structures, some form of two-dimensional display is bound to be superior, in that it builds up an anatomical picture instead of merely detecting reflecting surfaces (and the relative distance between them) in the path of a single ultrasonic beam. There are, however, two medical applications of the "A-scope" technique which have had extensive practical use. The first is the detection of shifts in the midline structures of the brain: extensive reference has already been made to this and it is discussed again in the appendix. The second is the detection of the widths of the chambers in the heart and the amount of movement in the heart valves; recent developments in this technique by EFFERT of Dusseldorf have resulted in these movements being recorded on a trace. (EFFERT and

DOMANIG, 1959). EFFERT'S method has been used in more than 2000 cases and provides a practical aid in cardiology as, for example, the amount of movement in the mitral valve before and after valvotomy can be measured.

It is believed that the method of foetal cephalometry described in the foregoing pages is also an application of ultrasound which has undoubted clinical value. "A-scope" is suitable for measuring the biparietal diameter because of the geometry of the foetal head and, where clear echoes are obtained, the interval between them can be measured with accuracy. The main difficulty lies in the interpretation of the "A-scope" trace, but this can be overcome with experience. The work cannot be done by a technician; obstetrical experience is necessary as careful abdominal palpation is an essential preliminary to ultrasonic scanning. It took the author and his physicist colleague considerable time before they learned some of the fallacies of interpretation, but they believe that, provided those who use it have had a little training, the method is suitable for general use in a maternity hospital.

For the patient, the examination is simple, does not involve the slightest discomfort and can be performed at the bedside. The result is immediately available to the clinician, a fact useful in emergencies. Reliable results can be obtained where x-ray cephalometry would be difficult or impossible - when the head is high or there

is a malpresentation. The examination is repeatable, which makes it a useful method of studying the growth of the foetal head and comparative results in the same patient are of great interest, especially in disorders affecting foetal growth. It is hoped that the method will be used by other workers in an attempt to elucidate some of the many problems of intrauterine development and that it may become a valuable aid to the practising obstetrician.

APPENDIX

ULTRASONIC ECHOENCEPHALOGRAPHY IN THE NEWBORN

The use of pulsed ultrasound, with A-scope presentation, for the diagnosis of intracranial lesions by finding deviations of the midline structures of the brain has been developed in recent years by LEKSELL (1956, 1958), KIKUCHI et al. (1957), GORDON (1958, 1959), LITHANDER (1960, 1961), JEPPSSON (1961), TAYLOR et al. (1961) and BRAAK et al. (1961). This technique of "echoencephalography" has already been discussed on page 21 . GORDON (1963) emphasises that it can be applied much more rapidly and with much less risk to the severely injured accident case than any angiographic or pneumographic investigations of the brain by x-rays. The simplicity of the examination and the immediate availability of the result has made the method attractive to neurosurgeons and McKISSOCK, speaking at the meeting of the British Institute of Radiology devoted to the use of ultrasound in December, 1962, spoke enthusiastically of its great practical value.

JEPPSSON (1961) suggests that echoencephalography may be particularly useful in small children in whom cerebral angiography is often technically difficult, if at all possible, but the use of the method in the newborn has not been reported.

At the Glasgow Royal Maternity Hospital the author has had the opportunity of examining a few cases of neonates who were known or suspected to have intracranial lesions, with the apparatus in use there for foetal cephalometry. In the hospital's Paediatric Department there has been a great deal of work devoted to the treatment of the pulmonary syndrome of the newborn. HUTCHISON et al. (1962) report the results of this treatment and emphasise the role of intracranial haemorrhage as a cause of death in the pulmonary syndrome. Of 27 patients in their series in whom the acidosis of the pulmonary syndrome was corrected by intravenous injections of sodium bicarbonate and glucose or fructose, with or without treatment in a pressure chamber, 11 died. Seven of these had large intraventricular or subarachnoid haemorrhages. HUTCHISON et al. state that "Intracranial haemorrhage resulting from anoxia has, of course, an adverse effect on the prognosis in premature infants: but unfortunately there are no clinical means whereby intracranial haemorrhage can be diagnosed with assurance in these very distressed infants". The ultrasonic technique was applied to 9 infants who were suspected of having intraventricular haemorrhage.

The technique used was the same as for measuring the neonatal biparietal diameter. The probe was placed on the side of the child's head and the echoes from the far side of the skull and the midline structures of the

brain located. Because echoes from structures near the probe surface are swamped by those of the skull margin nearest the probe it is not possible to discriminate lesions in the first few centimetres of brain and the examination has therefore to be performed first from one side of the head and then from the other, so that echoes along the whole path of the ultrasonic beam can clearly be visualised. (Fig. 60).

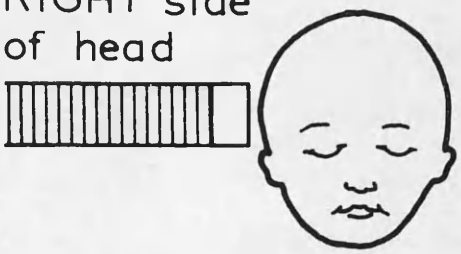
A Polaroid camera was kindly lent by Smith's Industrial Division so that it was possible to make a photographic record of some of the cases examined.

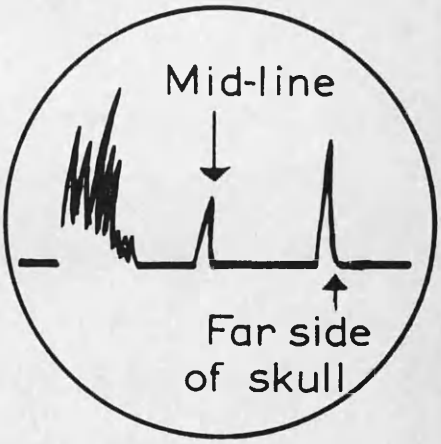
It was hoped that, if the ventricle were distended with blood or clot, an abnormal echo would appear between the echo from the midline and that from the skull margin. Ventricular dilatation can be demonstrated in this way in hydrocephalus as the following case illustrates.

ECHOENCEPHALOGRAPHY in the NEWBORN

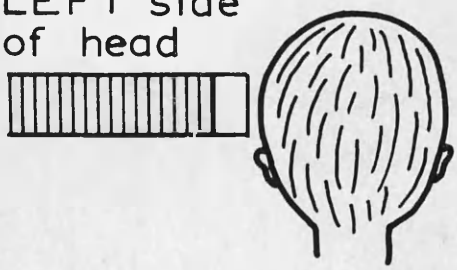
FIG. 60

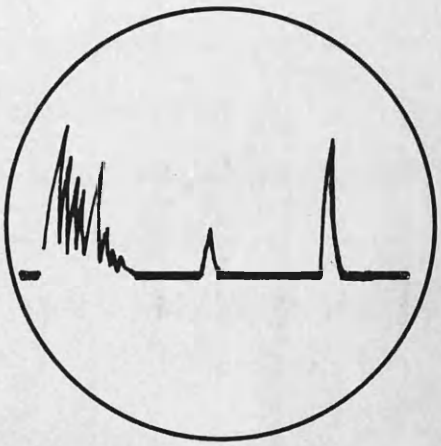
Probe applied to RIGHT side of head





Probe applied to LEFT side of head

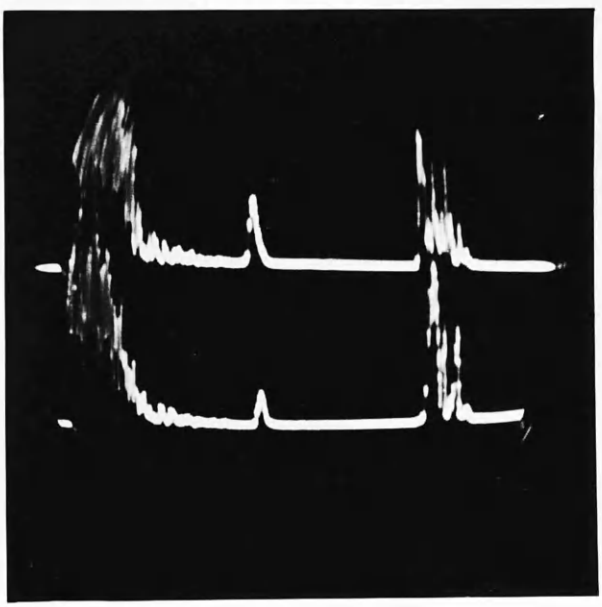




Combined photo. of result — Normal echoencephalogram

FROM L.H.S.

FROM R.H.S.



CASE NO. 1

Baby Magee, aged 8 days, had a minor degree of hydrocephalus, a spina bifida with myelomeningocoele and spastic legs.

Echoencephalography showed abnormal echoes thought to come from the lateral margins of the distended ventricles. Measurements (in microseconds) of the position of these echoes were made by the cursors used for cephalometry. After injection of air into the ventricles, a different picture appeared, echoes being equally spaced and decaying in an exponential fashion: these echoes were probably reverberations from the air-filled ventricles as air reflects ultrasound so strongly as to obscure other echoes.

An x-ray ventriculogram was then taken, confirming ventricular dilatation. (Fig. 61).

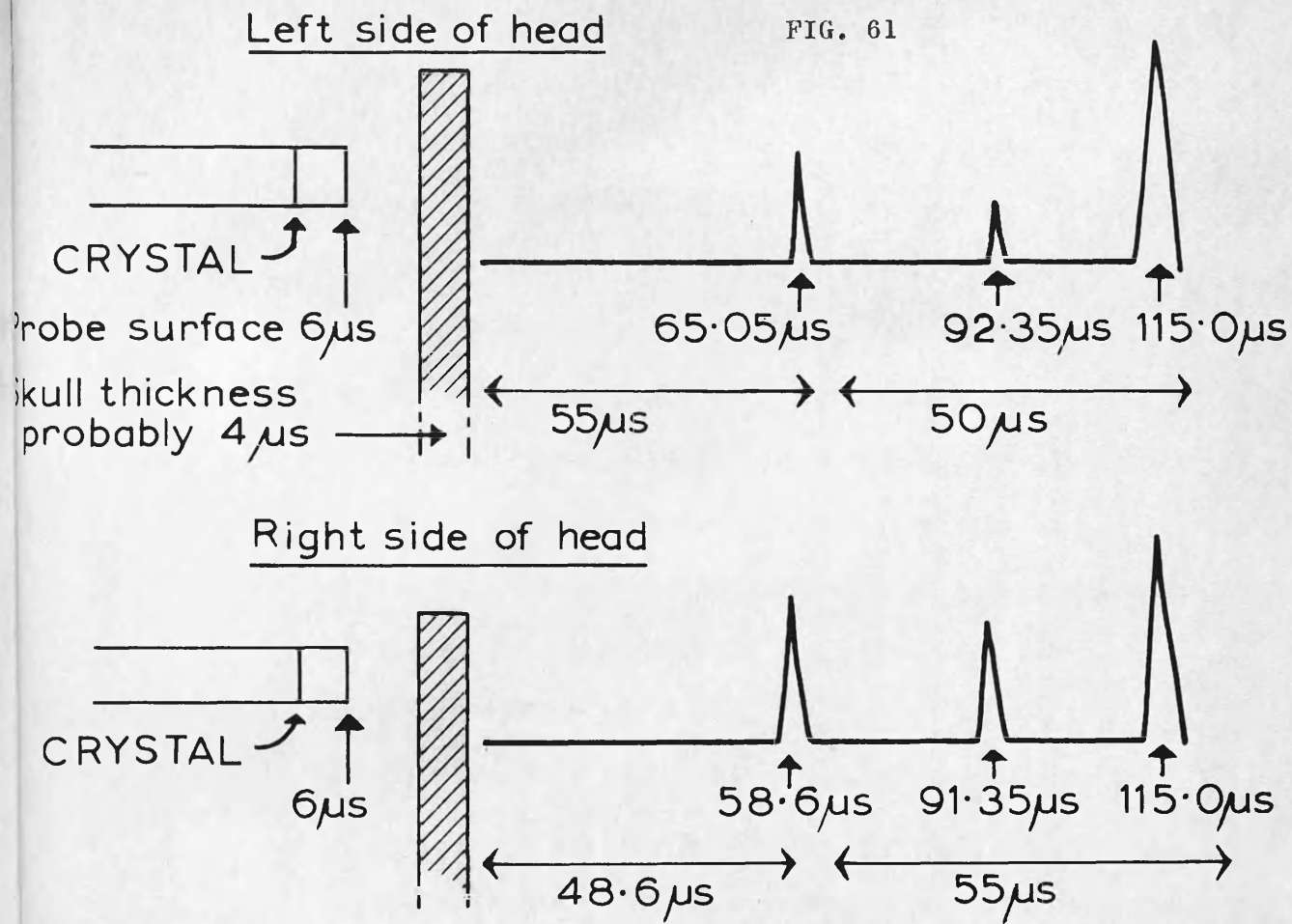
The following 9 cases were examples of the pulmonary syndrome of the newborn in whom intraventricular haemorrhage was suspected.

CASE NO. 2

Baby Kite, the second of twins, was born by manual breech extraction after premature labour at 30 weeks. He weighed 3 pounds 14 ounces (1.75 kg.) at birth. He was asphyxiated at birth, quickly developed respiratory distress and was found to be a case of Rhesus incompatibility. At $3\frac{1}{2}$ hours, exchange transfusion was attempted but was mechanically impossible. At

ECHOENCEPHALOGRAM IN HYDROCEPHALUS

FIG. 61



X-RAY VENTRICULOGRAM IN SAME CASE

L.H.S.

$4\frac{3}{4}$ hours the baby developed a marked respiratory acidosis but responded to treatment. His condition remained satisfactory until 36 hours when he began to have apnoeic attacks. Ultrasonic examination was performed at 43 hours. Prominent abnormal echoes were seen in the situation of the ventricles: there was no displacement of the midline echo. The findings appeared to be consistent with intraventricular haemorrhage. The baby died at 45 hours. Postmortem examination showed bilateral intraventricular haemorrhage, there being antemortem clot throughout both ventricles, tracking down the acqueduct and leaking around the base of the brain. (Fig. 62).

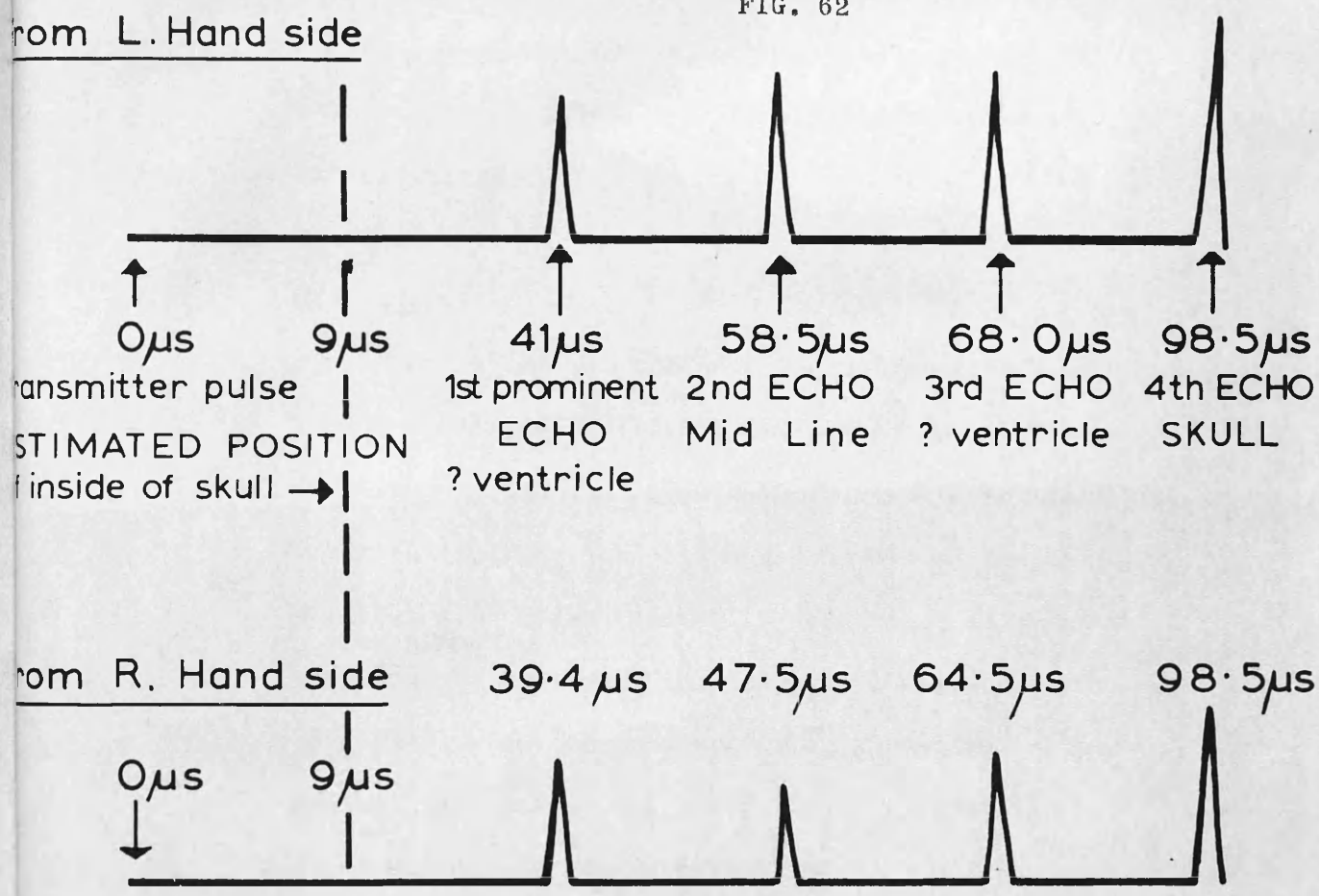
(This child's twin, who weighed $2\frac{1}{2}$ pounds (1.13 kg.) at birth, was examined at the same time and no abnormal echo was detected within the brain. The baby subsequently progressed well.)

CASE NO. 3

Baby Little was born at 31 weeks by assisted breech delivery and weighed $2\frac{1}{2}$ pounds (1.14 kg.) at birth. At 48 hours the baby had an apnoeic attack and several hours later began to have convulsive spasms with head retraction, cyanotic attacks and irregular respiration. Intracranial haemorrhage was suspected and ultrasonic examination was performed. No abnormal intracranial echo was noted. During the following 9 hours the baby

BILATERAL INTRAVENTRICULAR HAEMORRHAGE EMONSTRATED BY ECHOENCEPHALOGRAPHY (Case no. 2)

FIG. 62



SECTION OF BRAIN showing bilateral intraventricular haemorrhage

had frequent, prolonged apnoeic and cyanotic attacks preceding death.

Postmortem examination showed no naked-eye lesion in the brain. The death was classified as due to atelectasis.

CASE NO. 4

Baby Harley was admitted to the Paediatric Department in the second hour of life, having been born at home at 29 weeks' gestation. The child weighed 2 pounds 7 ounces (1.12 kg.) at birth and developed respiratory distress with marked metabolic acidosis: it responded very well to treatment initially but after 58 hours developed colour changes and frequent apnoea. Intracranial haemorrhage was suspected. Ultrasonic examination was performed at this stage and a photographic record of the result is reproduced in Fig. 63 . No convincing abnormal echo was detected. The child thereafter had long periods of apnoea and died at 77 hours.

Postmortem examination showed bilateral intraventricular haemorrhage.

CASE NO. 5

Baby Courtenay was delivered by Caesarean section at 34 weeks and weighed 5 pounds 3 ounces (2.34 kg.). The baby was noted to have only one umbilical artery. Respiratory distress was marked at birth but there was a

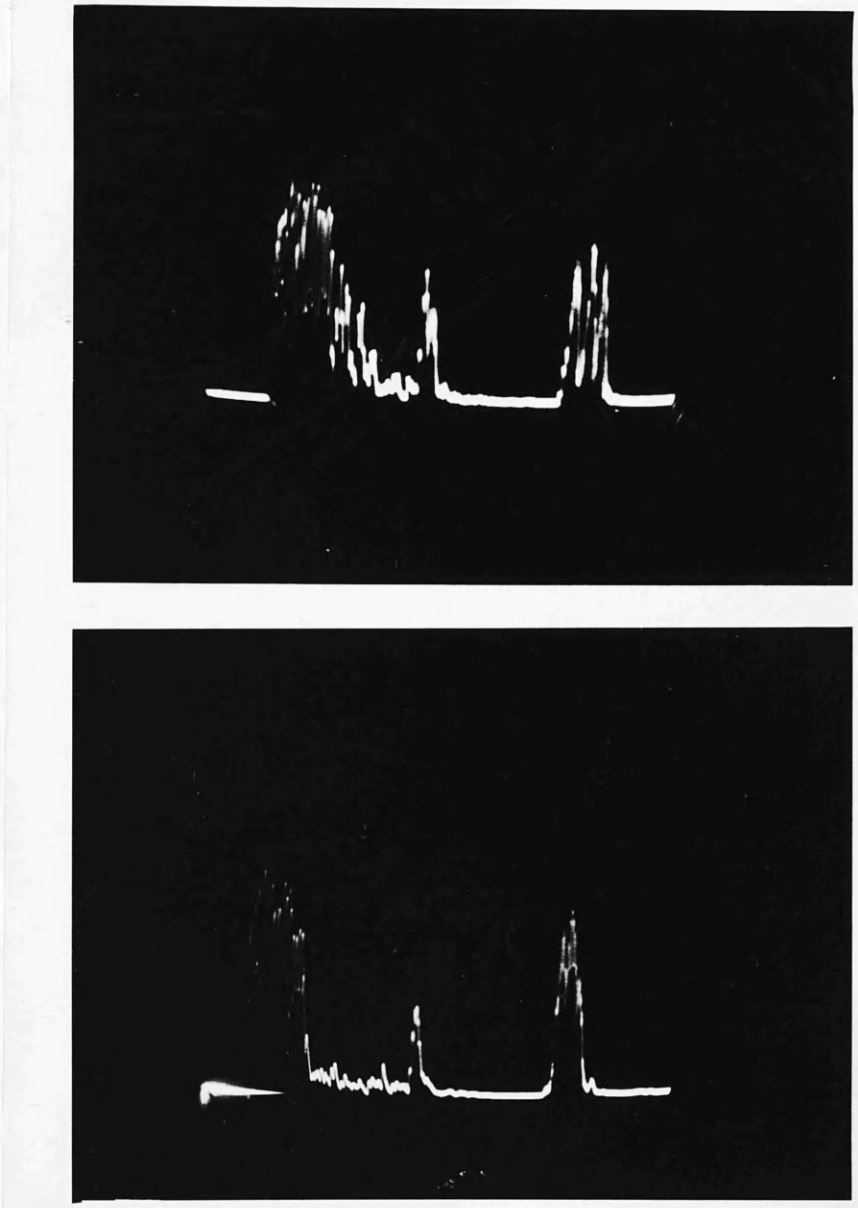


Fig. 63. Premature infant with respiratory distress syndrome and suspected intracranial haemorrhage. The result of echoencephalography is shown above. No convincing abnormal echo detected within the brain.

satisfactory response to treatment. At 80 hours, however, the baby began to have apnoeic attacks and cerebral haemorrhage was suspected. Ultrasonic examination showed no abnormality. The baby made a good recovery and was discharged home well.

CASE NO. 6

Baby Jackson weighed 3 pounds 14 ounces (1.75 kg.) at birth after premature labour at 33 weeks. The baby cried at birth but at 3½ hours had respiratory distress with marked metabolic acidosis. Response to treatment was satisfactory. Ultrasonic examination was performed at 25 hours and no abnormal echo was seen within the brain. The child progressed well.

CASE NO. 7

Baby Reilly, born by assisted breech delivery, weighed 5 pounds 7 ounces. The baby was difficult to resuscitate and at 45 minutes was placed in the pressure chamber. Breathing was established after 25 minutes in the chamber and the baby was placed in an incubator where it was noted to be restless and tense. An intracranial haemorrhage was suspected and ultrasonic examination was performed at 10 hours. No abnormal echoes were detected within the skull. The baby made a spontaneous complete recovery.

CASE NO. 8

Baby Barry was born at home at 32 weeks gestation and was admitted to the Paediatric Department at 2 hours. Respiratory distress was present on admission. Response to treatment was disappointing and after 18 hours there was marked deterioration with periods of apnoea. At 42 hours the baby showed evidence of cerebral irritation. Intracranial haemorrhage was suspected. Ultrasonic examination was performed at 46 hours and no abnormal echo was seen. The baby died at 54 hours.

Postmortem examination showed no evidence of cerebral haemorrhage.

CASE NO. 9

Baby Kerr was born by Caesarean section at 29 weeks and weighed 2 pounds 5 ounces. Respiratory distress developed soon after birth and the response to treatment was not satisfactory. Ultrasonic examination at $7\frac{1}{2}$ hours showed no abnormality. The baby died at 13 hours.

Postmortem examination showed haemorrhage in and around the cerebellum. There was no interventricular haemorrhage.

CASE NO. 10

Baby McQueen was admitted to the Paediatric Department an hour after breech delivery at home. The rest of the history was unknown. The baby weighed

2 pounds 4 ounces. Ultrasonic examination at 4 hours showed no abnormality. The baby died at 8 hours.

Postmortem examination showed no evidence of intraventricular haemorrhage: the death was due to asphyxia.

In the following case, ventricular dilatation due to hydrocephalus produced an abnormal echoencephalogram.

CASE NO. 11

Baby Gray was born prematurely at home and weighed 4 pounds 10 ounces (2.09 kg.). At 21 days, coliform meningitis was diagnosed. Repeated aspiration of the ventricles from 23 days removed blood and pus: streptomycin was instilled into the ventricles. Ultrasonic examination was performed on the 25th day and revealed a prominent abnormal echo on the right side of the brain. The findings were unchanged 5 days later. At the time of writing, 4 weeks later, the baby is still alive but the prognosis is regarded as hopeless. (Fig. 64).

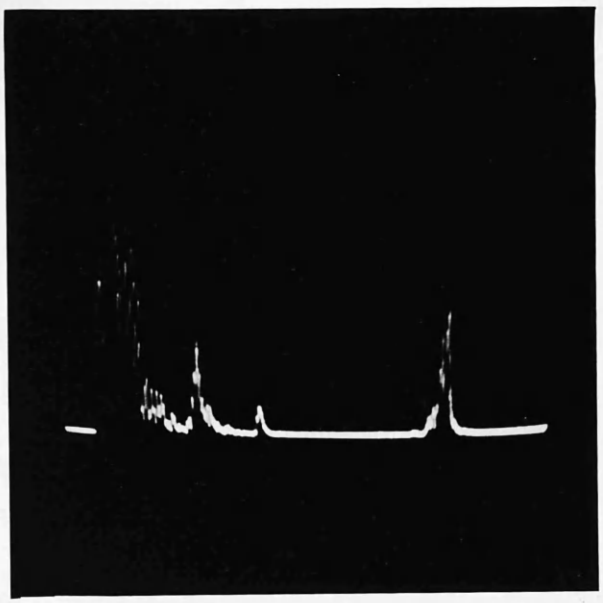


FIG. 64. Premature infant with B. coli meningitis. Echoencephalogram shows prominent abnormal echo to the right of the midline. Blood and pus obtained on ventricular aspiration.

SUMMARY AND CONCLUSIONS

Of 11 infants examined, there were abnormal echoes within the brain in 3; these were one case of congenital hydrocephalus, one of hydrocephalus resulting from meningitis and one case of bilateral intraventricular haemorrhage.

Of the remaining 8, in whom no ultrasonic abnormality was found, although intracerebral haemorrhage was suspected clinically in all of them, 3 recovered completely and 5 died. In 3 of these 5 there was no lesion in the brain; one had bleeding around the cerebellum which it would not have been possible to diagnose by ultrasonic examination; one was found to have intraventricular haemorrhage, but this may have developed in the 19 hours intervening between ultrasonic examination and death.

On the basis of this brief study, it would seem worthwhile to continue investigations by echoencephalography in the newborn, especially in view of the good published results of the method when applied to adults.

To continue the work, however, alternative equipment will be required, as the apparatus used for foetal cephalometry is not very suitable for the detection of intracranial lesions. Recent technical developments have produced apparatus which should make an extended study possible.

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