'Heartstart Scotland' Statistical analysis of survival from out-of-hospital Cardiac Arrest

by
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Abstract

In 1988 the Scottish Ambulance Service set out to equip all its 395 accident and emergency ambulances with Laerdal semi-automatic defibrillators. Semi-automatic defibrillators are devices that can administer an electric shock to a patient in cardiac arrest and shock the patient's heart back into a viable rhythm. The Heartstart Scotland study was set up to audit the defibrillation program, in particular the resuscitation success rate. It became apparent quite early on that the program was extremely successful and in the first year of the study the ambulance service successfully resuscitated 12.5% of all patients who were defibrillated.

In Chapter 1, I review the organisation of the Scottish Ambulance Service, the origins of the Heartstart Scotland study and the history of pre-hospital care from 1966 to date. It was in 1966 that Geddes introduced the concept of out-of-hospital defibrillation. Chapter 2 concentrates on the data collection and storage, and methods of patient follow-up. Data are collected from eight ambulance areas across Scotland's 76.000 km^2 and there are inevitably problems with data quality and collection. These problems were more acute in the early stages of the study when there was little consideration to questionnaire design and accuracy of ambulance crew responses.

Chapter 3 describes the Heartstart population in detail and touches on what factors during a patient's resuscitation attempt may influence their ultimate survival. It should be obvious to the reader that a cardiac arrest witnessed by a bystander is more likely to have a successful outcome than one that is not. Other factors, such as the effect of gender on outcome are less obvious.

It is important that the reader fully understands the sequence of events that are being analysed here. Chapter 4 is an overview of the whole system from patient collapse to hospital discharge. In 1991 a strict set of guidelines were published for reporting out-of-hospital cardiac arrest. This style of reporting is known as the 'Utstein style'.

In Chapter 5, factors influencing initial survival are identified using stepwise logistic regression techniques. Initial survival is defined as survival to hospital discharge. There are three stages leading to successful discharge. These are :-

- presence of a shockable rhythm following collapse
- admission to a hospital ward
- discharge from hospital alive

Different factors are shown to be significant at each stage.

Although there are many similar studies to Heartstart across the world, little research has been carried out into the long-term survival of patients following out-of-hospital cardiac arrest. Chapter 6 examines the characteristics of a group of 924 cardiac arrest patients who were admitted to a hospital ward . Long-term survival is defined as the duration of the patient's life following discharge from hospital. Product limit estimates of survival are presented for the 458 patients discharged alive to determine the univariate impact on survival of factors such as age, cause of arrest and drug therapy on discharge. Cox proportional hazards models were then applied to determine the multivariate effect on survival of the various factors. Patients were stratified according to underlying cause of arrest (Myocardial infarction (MI), ischaemia/non Q wave MI or primary ventricular fibrillation).

Chapter 7 is a general summary of this type of research looking at problems with result presentation and interpretation. A review of current and future research interests is presented, followed by my interpretation of the most interesting results arising from this thesis.

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CHAPTER 1

Introduction

1.1 Heart Disease in Scotland

Scotland covers an area of 76,000 square kilometres and has a population of approximately five million, three million of whom live in the central belt that encompasses Glasgow and Edinburgh. Coronary heart disease (CHD) is currently the major cause of premature death in the United Kingdom[1]. Over the last decade the importance of pre-hospital care in medicine has increasingly been recognised, largely because of the potential for saving lives. For many years it has been the case that pre-hospital care has been very limited comprising only basic life support . Ambulance personnel have in the past been thought of as 'scoop and runners', an approach that has generally been encouraged by the medical profession. It is however, now apparent that as a result of pre-hospital care, length of hospital stay can be reduced and quality of life after discharge can be improved dramatically. The Scottish Ambulance Service (SAS) participated in the "Early emergency care study: the potential benefits of advanced pre-hospital care" in the mid 1980s[2]. This study pointed to the fact that the greatest potential for reducing mortality outside hospital is in the cardiac area. The role of the Scottish Ambulance Service in providing pre-hospital cardiac care is therefore crucial to health care in Scotland as they are the obvious providers of this 'service'.

1.2 Organisation of the Scottish Ambulance Service

The Scottish Ambulance Service is a national service, split into eight operational areas and run by a General Manager (as of April '92) based at the National Headquarters in Edinburgh. It provides an accident and emergency (A&E) ambulance service and a patient transport service. The accident and emergency units attend emergency calls, and transport patients between hospitals when some kind of medical support is required (e.g. if the patient is receiving a drip or requires oxygen therapy). They are well equipped to cope with most types of emergencies. The majority of units are two manned, with one crew member driving and the other acting as an attendant. The attendant is primarily concerned with the patient's treatment, and subsequent completion of any required paperwork. The patient transport service is essentially a taxi service to transport patients

between home and hospital or between hospitals (where no therapy is required). It was in 1986 that the two parts of the service were officially split and at that time there was a trend for the older crew members to join the patient transport service. In some areas (e.g. Highland Region) the ambulances still serve both purposes and are often single-manned.

This project will be solely concerned with the units that provide A&E cover.

1.2.1 Accident and Emergency Service

There are a total of 395 accident and emergency units in service, split across the eight areas within Scotland, as shown in appendix 1. At present there are 1500 front-line ambulance personnel in Scotland, including approximately 200 fully qualified paramedics. When there is a more acute medical emergency such as a cardiac arrest, or when there is a serious road traffic accident (RTA) these ambulances sometimes receive medical back up from medical rapid response units (such as Medic I based at Edinburgh Royal Infirmary, manned by a minimum of two Doctors, one of whom will be of registrar status, a nurse and an ambulance crew member driving). These units are equipped to provide advanced life support. Now that the paramedic training scheme is established, there is generally a paramedic attending every serious emergency call either as a member of the two man crew attending the incident or as a separate paramedic response. Paramedics are trained in most of the skills that the medical rapid response units can provide and it is hoped that their presence at serious incidents will reduce pre-hospital mortality across Scotland.

1.2.2 Types of Emergency Call

There are two types of emergency call that the A&E units attend, '999' emergency calls (a system now established for about 50 years) and general practitioners' (GPs') urgent admission calls. There are approximately 0.5 million of one or other of these calls annually. A GP can place a degree of urgency on a call (e.g. Emergency, Urgent 1 hour or Urgent 2 hour). This can lead to delays in patient treatment in out of hospital cardiac arrest when the GP logs the call as urgent and the patient arrests in the interim. The Department of Health and Social Security (DHSS) ORCON regulations[3] state that if a call is logged on the '999' emergency system, 50% of the time the ambulance must be on the scene with the patient within eight minutes and 95% of the time within twenty minutes. The timings for a metropolitan area such as Greater Glasgow are seven and fourteen minutes respectively.

1.3 The Origins of the 'Heartstart Scotland' Study.

In 1987 the National Health Service Training Authority (NHSTA) introduced a scheme[4] to enable ambulance personnel to be trained in intubation, infusion, cardiac arrhythmia recognition, defibrillation and the use of cardio-active drugs. The Scottish Ambulance Service management decided that a scheme like this was too ambitious and costly. If a patient goes into cardiac arrest the single most critical determinant of outcome is the use of a defibrillator [5,6]. If the time between arrest and defibrillation is very short (less than five minutes) then the probability of a successful resuscitation based on the Heartstart Scotland experience is about 50%. On a limited budget therefore training in defibrillation alone would have the most impact on survival.

1.3.1 St. Andrew's Operation Heartstart

In 1987/88 a pilot project was set up in St Andrew's and East Neuk in Fife, Scotland, to raise funds for the purchase of five defibrillators to equip all the area's A&E ambulances. The idea was that the crew would transport the defibrillator to the scene of the collapse for use by a General Practitioner (GP). This scheme was called " St. Andrews Operation Heartstart" and was successful enough to justify wide use of defibrillators across Scotland.

1.3.2 The Launch of Heartstart Scotland

In October 1988 the Scottish Ambulance Service launched the "Heartstart Scotland" campaign together with the British Heart Foundation. The launch was on national television and gained extensive associated press coverage. The campaign's aim was to supply every A&E ambulance in Scotland with a defibrillator and to supply resuscitation manikins and cardiac arrhythmia simulators to every ambulance station and training centre . The enthusiasm for fund-raising was tremendous and funds accumulated rapidly. By mid 1990 all Scotland's ambulances were equipped with AEDs.

Manual and automatic defibrillators were both considered. Ambulance crews would be required to recognise principal arrhythmias in the case of manual defibrillators and it was thought that skills retention could be a problem . Because constant retraining would have been very expensive the idea was rejected. The automatic defibrillators were rejected because of the cost of the defibrillation pads (£16 a set) that had to be used during every event of cardiac arrest or monitoring. At that time semi-automatic defibrillators were about to appear on the market. These would use standard National Health Service (NHS) electrodes for monitoring only purposes and would only use the costly pads for defibrillation. Approximately 85% of cardiac cases only require the patient to be monitored [7].

After evaluation of the various types of defibrillator available, it was decided to adopt the Laerdal 2000 defibrillator together with its training aids (Laerdal Skillmeter Resusci-Anne and Mini Heartsim). More recently (since around January 1991) the Laerdal 3000 has also been in use. It is slightly more sophisticated than its predecessor and can be operated manually. Both machines weigh about the same as portable typewriter (the 3000 is lighter than the 2000) and use vocal prompts to the crew to check the patient and analyse the patient's heart rhythm. The defibrillation pads and monitoring electrodes are kept in the machines cover. When the crew attend an emergency call they should always carry the defibrillator to the scene, as seconds are crucial if a cardiac arrest should occur while they are attending the patient. Even if the call is non-cardiac related, cardiac arrest can occur.

1.3.3 Laerdal 2000 & Laerdal 3000 - Treatment Protocol

All cases of chest pain or collapse, in patients of 10 years of age or over are cardiac monitored. Patients who are obviously dead by virtue of decomposition or post-mortem staining are excluded. If an arrhythmia arises and is diagnosed by the automated external defibrillator (AED) to require defibrillation the device advises the ambulance crew that a shock is indicated by giving a visual and audible "check patient " message. A strict protocol is adhered to, in order to minimise the possibility of inappropriate defibrillation. Initially, the crew must confirm cardiac arrest by ensuring the patient is unconscious, apnoeic (not breathing) and has no palpable pulse . If the patient remains in a treatable rhythm the machine will prompt "press to analyse". If the crew recognise that defibrillation is necessary they may request an analysis without waiting for a "check patient " prompt by pressing the "press to analyse" button. Following the analysis request the AED confirms the presence of a treatable rhythm and initiates charging before

advising the crew to "press to shock". The delivery of a DC shock requires two crew decisions without which the AED cannot deliver a shock. The shock is delivered through two self adhesive 12cm pads. The protocol (figure 2) allows a maximum of 12 shocks to be delivered in groups of three with cardiopulmonary resuscitation (CPR, see definition in section 1.4) being re-established for 1-2 minutes between each group. The first two shocks are at 200J and all subsequent shocks at 360J. Cardiopulmonary resuscitation is maintained at all times other than during rhythm analysis or defibrillation.

Following each completed resuscitation attempt the memory module from the defibrillator is downloaded as a printout for later analysis. The printout consists of a summary page (figure 3) containing the time the unit was switched on, times of all AED messages issued such as "check patient"; all crew instructions such as "analyse"; times of the defibrillatory shocks and the energy selected and unit off times. It also contains a printout of the patient's electrocardiogram (ECG) rhythm strips with transthoracic impedance for each shock (figure 4).

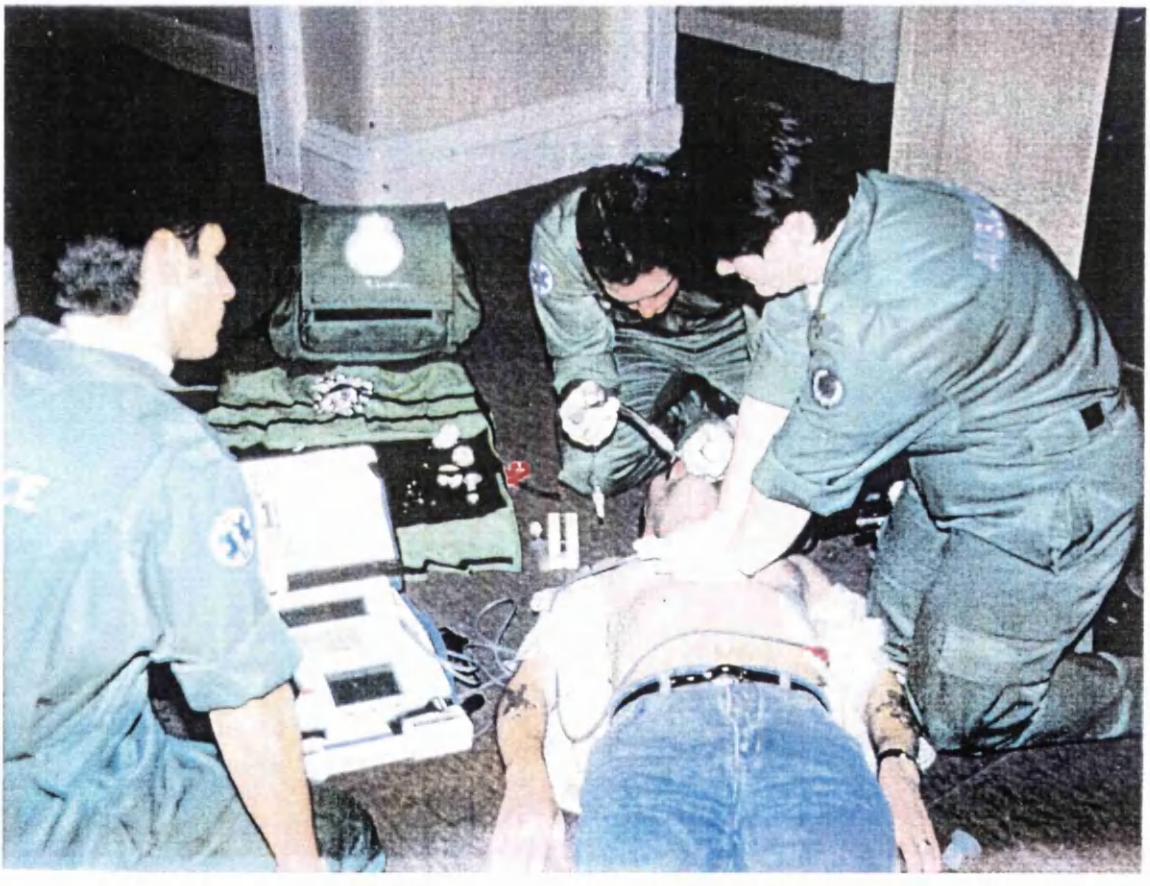


figure 1 - Ambulance technicians training in Heartstart protocol

Ambulance crew training in CPR took place in groups of six crew per instructor and the training lasted eight hours (figure 1). The eight hours comprised four hours defibrillation training and four hours of cardiopulmonary resuscitation (CPR) revision. Resuscitation mannequins were used for training in CPR and defibrillation.

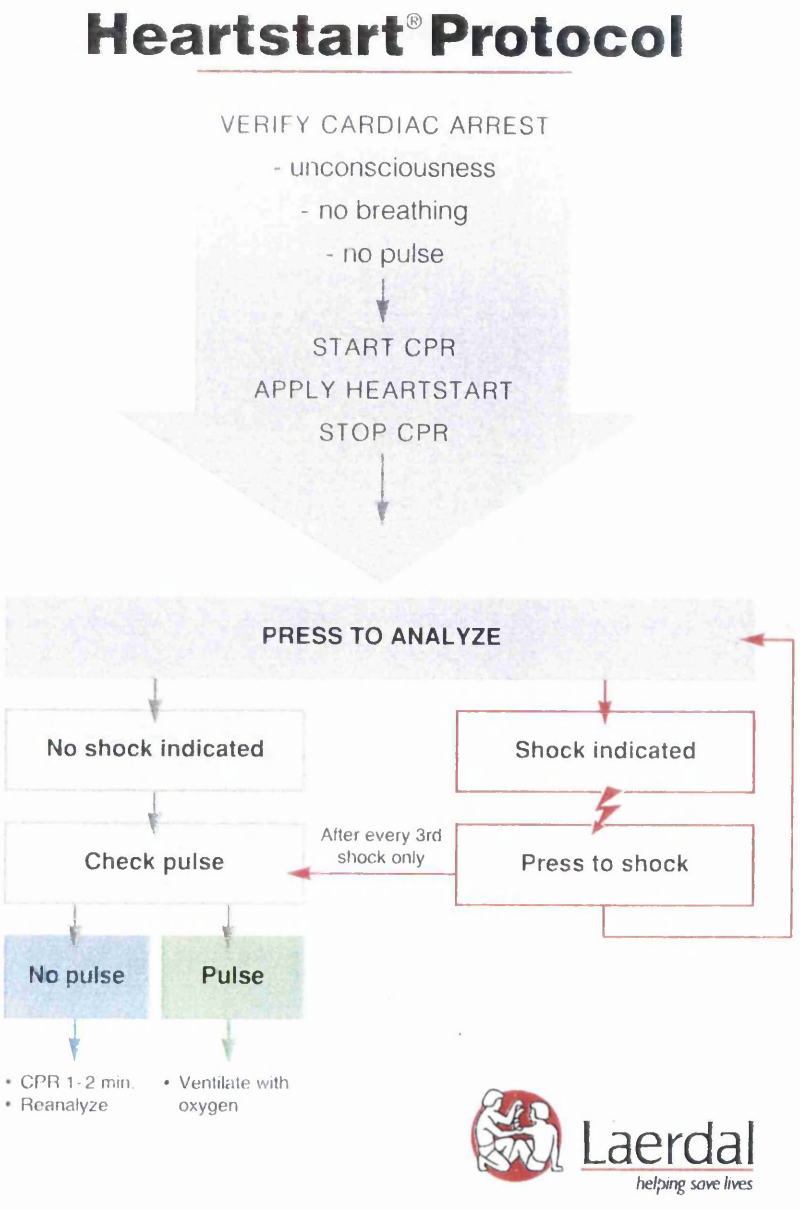


figure 2 - Treatment protocol

HEARTSTART 2000 RUN REPORT

REPORT DATE __/__/__ TECHNICIANS _____

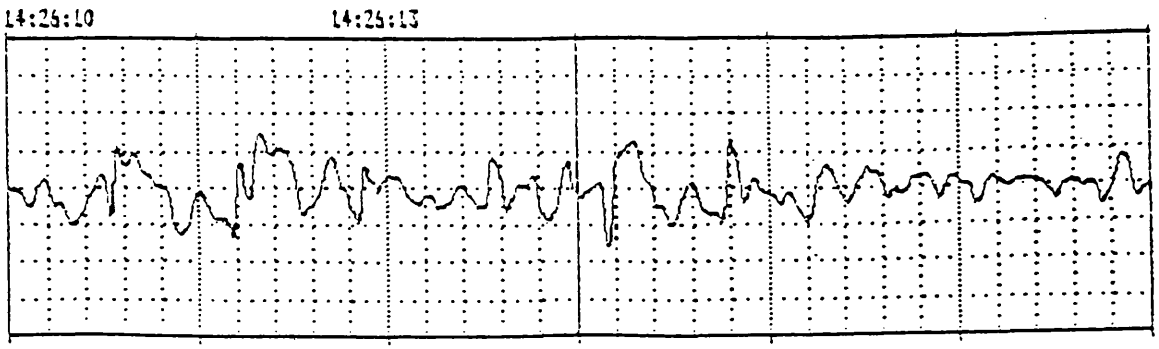
_____

EPISODE DATE . . . . . 29 MAY 94 PART NUMBER 900055
EPISODE TIME . . . . . 14:26:10 SERIAL NUMBER 001574
MCM S.W. VERSION . . . . 1.10 DEFIB. S.W. VERSION . 2.01
LHR S.W. VERSION . . . 1.00

EVENT LOG:

———	DATE: 29 MAY 94 ———
14:26:10	UNIT ON
14:26:17	START ANALYSIS
14:26:21	START CHARGING
14:26:24	COMMIT TO TREAT
14:26:29	READY TO SHOCK
14:26:30	SHOCK NUMBER 1 DELIVERED, 200 JOULES
14:26:37	START ANALYSIS
14:26:44	SHOCK NOT INDICATED
14:26:46	START ANALYSIS
14:26:52	SHOCK NOT INDICATED
14:29:31	CHECK ELECTRODES MESSAGE GIVEN
14:29:37	CHECK ELECTRODES MESSAGE CLEARED
14:38:01	CHECK ELECTRODES MESSAGE GIVEN
14:38:02	CHECK ELECTRODES MESSAGE CLEARED
15:15:50	CHECK PATIENT MESSAGE GIVEN
15:16:00	START ANALYSIS
15:16:04	START CHARGING
15:16:07	COMMIT TO TREAT
15:16:12	READY TO SHOCK
15:16:16	SHOCK NUMBER 2 DELIVERED, 200 JOULES
15:25:13	CHECK ELECTRODES MESSAGE GIVEN
15:25:21	CHECK ELECTRODES MESSAGE CLEARED
15:31:14	UNIT OFF

RECORDED ECG DATA:



PRESENTING
RHYTHM

figure 3 - Summary output & presenting rhythm

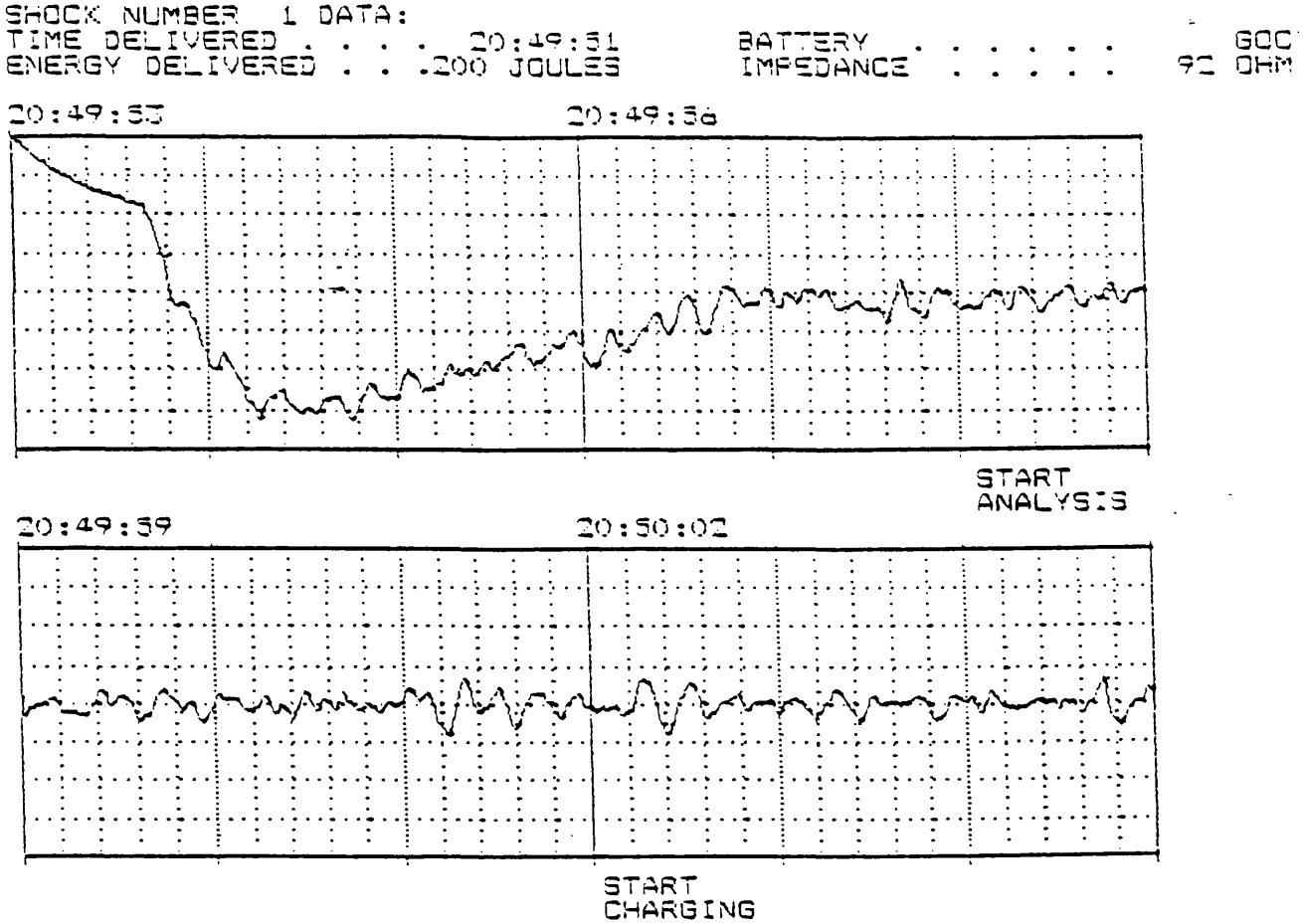


figure 4 - 1st shock delivery & data

1.4 The Heart and Resuscitation

The heart is a muscular pump that drives the blood around the body (figure 5). The right side of the heart receives blood from the body and pumps it through to the lungs. The left side receives oxygenated blood from the lungs and pumps it via blood vessels to the rest of the body. The receiving chambers of the heart are called ***atria*** and the thicker walled pumping chambers are called ***ventricles***. Blood flow through the heart is maintained in a forward direction by the presence of valves. Arteries carry blood from the heart. Veins carry blood towards the heart.

The heart pumps at a rate of about 70 beats per minute (bpm), and outputs about 5 litres per minute at rest. The contraction of the heart muscle is known as ***systole*** and the relaxation period as ***diastole***.

Electrical impulses from a group of cells in the right atrium control contractions and these impulses travel along pathways that branch out to muscle fibres in all 4 chambers.

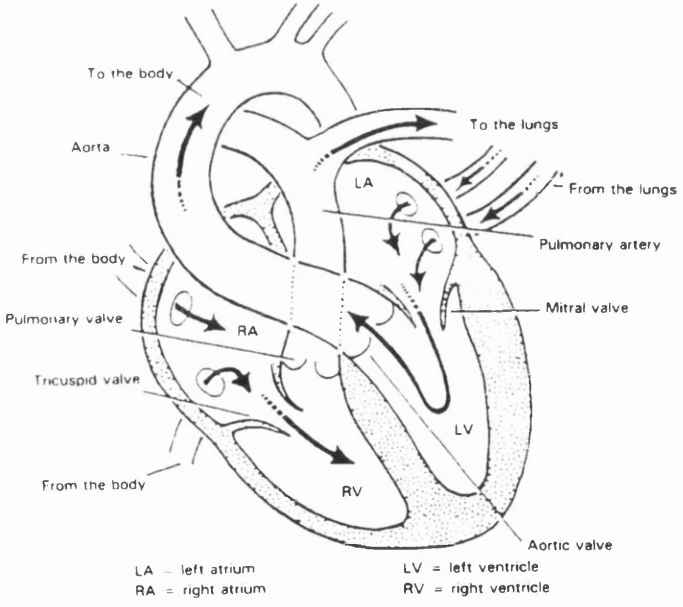


Figure 5 - The heart, from BHF Heart Information Series No.13 (page 3)

Coronary Heart Disease (CHD)

CHD causes narrowing of the coronary arteries resulting in reduced blood supply to the heart muscle.

Ischaemia

Medical term for shortage of blood to an organ such as the heart.

Infarction

Death of tissue through lack of blood.

Heart failure

Reduced pumping ability of the heart.

Cardiac Arrest

Cardiac Arrest is the cessation of cardiac mechanical activity, confirmed by the absence of a detectable pulse, unresponsiveness and apnoea (or agonal, gasping respirations).

Cardiopulmonary Resuscitation (CPR)

CPR is a broad term meaning an attempt to restore spontaneous circulation. CPR can be classified as successful, unsuccessful, basic or advanced.

Basic CPR

Attempt to restore effective circulation with external compressions of the chest wall, plus expired air inflation of the lungs. Rescuers can provide ventilation through airway adjuncts or face shields appropriate for use by lay public (this excludes Bag & Mask, Intubation and airway devices that pass the pharynx).

Advanced CPR

Attempts to restore spontaneous circulation with basic CPR plus advanced airway management and ventilation techniques, defibrillation, and intravenous or endotracheal medications.

1.5 Pre-hospital Cardiac Care

"As certain as the continuing development of pre-hospital medicine is the increasing involvement of the general public in the immediate management of those stricken with chest pain or apparent sudden death. The right people need to know the minimum information which will enable them to resuscitate, summon appropriate assistance, and sometimes defibrillate" [8]

1.5.1 The History of Out-of-Hospital Cardiac Arrest

The concept of pre-hospital coronary care is that of taking the care to the patient and then as necessary transporting the patient to hospital. It is known that 40% of deaths relating to ischaemic heart disease occur within one hour of the onset of symptoms. In middle age and younger males 63% of the deaths occur within one hour [9]. This would imply that the majority of cardiac arrests occur out of hospital. More than 90% of these arrests are due to an arrhythmia of the heart known as Ventricular Fibrillation (VF). VF is potentially reversible by DC shock. The argument for some kind of pre-hospital coronary care is therefore very strong.

The first milestone in this field was the introduction of a mobile coronary care unit at the Royal Victoria Hospital, Belfast on the 1st January, 1966. Frank Pantridge and John Geddes[8] identified what a lack of skills and equipment there were to help the individual with a heart attack in the street. Pantridge recognised after observing patterns in treatment that myocardial damage resulting from Ischaemia could be influenced after its onset. The mobile coronary care unit that was set up was manned by a doctor, a nurse, a medical student and a driver. It contained all the necessary equipment for advanced cardiac life support (ACLS). This equipment included the first ever portable defibrillator . It was a mains operated defibrillator powered by car batteries through a static invertor. Through the years portable defibrillators have become smaller, lighter and easier to use to the extent where a trained lay person could successfully resuscitate an individual without posing any danger to himself or the patient.

Since that first study in Belfast similar studies have been conduted across the world. However, study protocols vary widely causing problems when trying to compare one to another. There are obvious differences in the various studies. These include :-

- number of patients in the study population
- area size

- demography and relief of area

Also more subtle differences such as definition of success, subset of patients analysed and length of patient follow-up.

The number of studies is large and most papers are similar in structure but use different figures and outcomes. For this reason only a subset, those of greater significance, will be summarised here. There are two authors in particular who have been investigating the subject of out-of-hospital cardiac arrest for nearly two decades. They are Richard Cummins and Mickey Eisenberg of Seattle, Washington, U.S.A.

Mickey Eisenberg [6], studied the population of 598,000 in suburban King County, adjacent to Seattle. A case was defined as being a person with heart disease experiencing out of hospital cardiac arrest caused by VF and who received CPR. Only patients where collapse was directly witnessed or heard were included. It was stated that patients not in VF or those whose arrests were not witnessed were unlikely to benefit from defibrillation.

Between 1st June 1979 and 30th June 1982, 595 cases satisfied the entry criteria. Excluded from the analysis were 26 who collapsed after paramedics arrived and 29 with missing time values, leaving 540 (91%) of cases. There were 42 emergency medical technician (EMT) vehicles equipped with portable defibrillators modified with a two channel cassette recorder to take continuous ECGs and voice recordings. The EMTs were allowed to deliver up to three 320 Joule shocks. The difference in success rate between Basic EMT + Paramedic intervention and EMT with defibrillator (EMT-D) + Paramedic intervention was not significant. What was significant, however was the same comparison where the delay from EMT arrival to paramedic arrival was greater than four minutes. In this case there was a 38% discharge alive from hospital rate with EMT-D + Paramedic as opposed to an 18% success rate with only basic EMT + Paramedic. One important point was that it took 2-4 minutes for the EMTs to initiate defibrillation due to time initiating CPR, attachment of electrodes and rhythm interpretation.

Eisenberg and Cummins[10] set out to compare the success rate of automatic external defibrillators (AEDs) as opposed to that of standard manual defibrillators within the same study area of King County. In all, 321 patients were treated. 116 patients were treated by EMTs using AEDs; 158 by EMTs using standard defibrillators and 47 using standard defibrillators when assigned AEDs. There was no difference in outcome across the groups but a significant difference was detected for time from power on to 1st shock, 1.1 minute in the AED group and 2 minutes in the standard defibrillator group. This paper highlighted the fact that AEDs are comparable with standard defibrillators and should be considered

as an alternative. They appear to have advantages in training, skills retention and faster operation. Such devices make early defibrillation available to a much wider population and are a major innovation in the area of pre-hospital coronary care.

Kenneth Stults[5] stated that survival after out-of-hospital cardiac arrest is poor in communities served only by basic ambulance services and added that conventional pre-hospital care is not an option for most rural communities. The rural communities in question were from Iowa, U.S.A.. From October 1st 1981 until May 31st 1983, 30 rural communities within the region participated in the study. There were 12 communities in the control group and 18 communities in the experimental group. Ambulance technicians in the experimental group (n=234) were trained to use portable monitor defibrillators (Lifepak 5) with two channel cassette recorders to record the patient's electrocardiogram as well as the voices of the emergency medical service personnel. Ambulance personnel in the control group (n=120) used only the monitor-recorder portion of the device. Both groups were trained identically , with the exception of the defibrillation training.

During the 20 month period, 162 cardiac arrests occurred in the 30 communities. All were attributable to heart disease. The incidence of cardiac arrest was similar in the two groups. 110 of the events occurred in the experimental group and of these 68 received one or more defibrillatory shocks. In total 12 (11%) patients in this group were discharged alive from hospital vs. 1 (2%) in the control group. In both groups a similar proportion were in VF when the ambulance crew arrived. The conclusion was therefore that the rate of survival was significantly higher in the communities where the ambulance personnel were trained in defibrillation.

1.5.2 The Chain of Survival

The best possible chance of any individual surviving an out of hospital cardiac arrest is when the following sequence of events occurs as quickly as possible[11].

1) Recognition of early warning signs
2) Activation of the emergency medical system
3) Basic cardiopulmonary resuscitation
4) Defibrillation
5) Intubation
6) Intravenous administration of medicines.

This important sequence of events has been labelled the 'Chain of Survival' concept. There are four vital links in this chain ; Early Access, Early CPR, Early defibrillation and Early Advanced Cardiac Life Support.

1.5.2.1 Early Access

When sudden cardiac arrest occurs access time begins at the moment of collapse. Access time includes recognition of the emergency; decision to make the call ; location of a telephone and the correct emergency number (in some parts of the world there are several numbers, many very difficult to remember[a]); interrogation of the caller by ambulance control; the decision to send an emergency vehicle[b] ; call processing time and emergency vehicle mobilisation time. Once the responder is notified, ambulance response time begins.

One way to reduce access times is to provide more ambulances. This method is expensive and inefficient. A previous study[12] showed that response time varied inversely as the square root of the number of vehicles per square mile implying that an 80% increase in the number of vehicles reduced average response time by one minute. The cost of this increase in vehicles would be phenomenal.

A more efficient way to reduce response times would be to improve the dispatch system and to increase public awareness. There are many problems to overcome when trying to educate the public to call for help early. People unaware that chest pain and respiratory arrest often precede cardiac arrest will delay the call for help until collapse occurs. Even when a collapse has been witnessed, the witness will telephone relatives, neighbours or the patients GP before calling the emergency number. Lack of a three digit emergency number, such as '999' in the UK or '911' in the USA can cause confusion and delays because witnesses call the wrong number.

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[a] In Chile, there is an emergency number for each private hospital. Response times of ambulances in the public system are around 2 hours (personal communication Dr Escobar).

[b] Not relevant on the UK '999' system as an emergency vehicle is automatically dispatched.

1.5.2.2 Cardiopulmonary Resuscitation

"A potentially life-saving intervention should never be withheld from a clinically dead person for fear of causing harm."[13]

The second link in the "chain of survival' is early CPR. The value of early CPR is that it can buy time for the cardiac arrest patient by producing enough blood flow to the central nervous system and the myocardium to maintain temporary viability. Early CPR is defined as CPR initiated within 4-5 minutes of the collapse occurring. Research has shown that when CPR is initiated early, the patient is more likely to be in ventricular fibrillation when the first responders arrive. It has also been shown that victims who receive early CPR are more likely to convert to a cardiac rhythm associated with restoration of spontaneous circulation (ROSC).

Richard Cummins and Mickey Eisenberg published a paper[13] in 1986 on American Style CPR. The issue addressed was whether or not people performing CPR could do harm to those in cardiac arrest and whether CPR training schemes train people to an adequate level of skill that will be remembered over time. The other obvious question is of course "Does CPR save lives?".

Probably the best example of CPR in the community dates back over 20 years to the scheme set up by Leonard Cobb and colleagues in Seattle[14]. By 1985, 450,000 people had been trained in CPR in Seattle and King County . The result of the scheme was that 50% of people arresting were given CPR by a bystander. One comment made was "Seattle and King County, Washington are the best places in the world to have a cardiac arrest and the worst places in the world to have a faint!". Data on 3000 cardiac arrest patients who were given CPR by bystanders and/or medical personnel suggested that there was no evidence of anyone inflicting harm on people who had not actually arrested.

It is possible that someone can be successfully resuscitated and then subsequently die due to injuries sustained from CPR e.g. gastric rupture. These incidences are extremely rare. A study of 400 survivors of cardiac arrest in King County failed to detect any adverse consequences due to CPR . In the experience of the authors, early initiation of an approximation of standard CPR rather than an exact counting and sequencing is the key. Conventional closed chest resuscitation produces flow rates through the carotid and coronary arteries that are so low (<15% of normal) that they challenge the ability of CPR to contribute to human resuscitation . Clinical experience however, shows that in most cases CPR does have benefits to survival if initiated within four minutes. In the

experience of the authors early CPR by people in the community increases the chance of survival by 50% to those given delayed CPR. The implication here is that in areas where the ambulance cannot reach the scene within 4 minutes community CPR training is necessary. The effect of CPR is to slow the dying process. It can neither sustain life nor restore a perfusing rhythm and is therefore of little use unless advanced cardiac life support (ACLS) arrives within minutes.

1.5.2.3 Early Defibrillation

The purpose of defibrillation is to re-establish a normal spontaneous rhythm in the heart. Technicians equipped with semi-automatic defibrillators have the potential to take early defibrillation to the patient. Almost 85% of persons with ambulatory, out-of-hospital primary cardiac arrhythmias experience ventricular tachyarrhythmias during the first minutes following collapse[11] . At first, proposals to allow less well trained emergency personnel to operate defibrillators provoked controversy. Thankfully, most of these initial concerns have now disappeared. Clinical studies have shown that systems using automated defibrillators can deliver the first shock up to 1 minute faster than manual defibrillators, due to their ease of use and the speed at which they operate. These machines are now being introduced into such areas as airlines, sports stadia, railway stations and cardiac rehabilitation programmes, further reducing the time between cardiac arrest and that crucial first defibrillatory shock.

1.5.2.4 Early Advanced Cardiac Life Support (ACLS)

In many cases CPR and defibrillation alone do not achieve or sustain resuscitation and endotracheal intubation and intravenous medication are necessary. No system, however should delay the start of an early defibrillation program because of the absence of paramedics or medical rapid response units[11]. In some systems when the first responder is a paramedic or doctor manned ambulance providing ACLS, response times are elongated and outcomes are poor. Such systems would benefit by being abandoned in favour of, or being supplemented by early defibrillation by EMT-D technicians. Opinions are mixed on the value of ACLS as opposed to EMT-D only as an out-of-hospital intervention and most of the evidence seems to point to best results when both tiers are provided as long as the first responder carries a defibrillator.

CHAPTER 2

Cardiac Care Forms, Design and Data Collection

2.1 Origins of Data Collection

It was important to audit the defibrillation program. Due to time constraints, initially only the Edinburgh and district data were followed through to patient discharge from hospital. Each time a patient was defibrillated a form (appendix 2) was completed by the ambulance crew seeking patient details, history of timings, whether or not the arrest was witnessed, time of arrest, whether or not CPR was initiated etc.

Between October, 1988 and September, 1989 there were three different designs of cardiac care forms in use . Throughout the year forms were completed for two types of event

1. Patients that were monitored by the Laerdal 2000 defibrillator for one or more of the reasons as outlined on the form (e.g. chest pain, history of heart disease, patient unconscious) but were not defibrillated.

2. Patients that were monitored and a "Check Patient" message was given leading to the application of the large defibrillator pads and subsequent defibrillation.

The study would largely be concerned with the second type of event. Also of interest were the cases when patients died but were at no time in a shockable rhythm after the crews arrived on the scene.

The purpose of analysing the non-shocked group was to check the accuracy of the Laerdal machines to check that they were prompting to shock when a shock was required. Further information was taken from printouts obtained from the ECG memory control module (MCM) attached to the defibrillator. All recorded rhythms were analysed and classified by one medical observer . Instances where an apparent misdiagnosis of rhythm had occurred were reviewed by a second more experienced medical observer and discussed with the technical staff of the manufacturer before final classification. It was vital to investigate whether the defibrillators were prompting to shock only under the correct rhythms (figure 6).

1. Ventricular Fibrillation (disorganised rhythm >100 beats/min with > 0.1 mV baseline variation)* or
2. Ventricular flutter >100 beats/min
3. Ventricular Tachycardia monomorphic >180 beats/min
4. Polymorphic Ventricular Tachycardia >180 beats/min

Figure 6. Shockable arrhythmias

In order to check that the machines were performing accurately, an analysis of the sensitivity and specificity of the machine and the system was carried out[15].

A **true positive(TP)** shock was defined as a shock delivered when the available 3 second rhythm strips suggested a shockable rhythm.

A **false positive(FP)** response was defined as a shock delivered when the available 3 second rhythm strips suggested a non shockable rhythm.

A **true negative(TN)** response was defined as no shock administered when a non-shockable rhythm was present.

A **false negative(FN)** response was defined as one or more 3 second rhythm strips of shockable rhythm with no record of a non shockable rhythm within the following 15 seconds, but with no resulting shock.

Sensitivity is defined as :-

$$\frac{\text{number of true positives}}{\text{number of true positives} + \text{number of false negatives}}$$

Specificity is defined as :-

$$\frac{\text{number of true negatives}}{\text{number of true negatives} + \text{number of false positives}}$$

Number Patients	Number Rhythm Strips	TP	FP	TN	FN	Sensit-ivity (%)	Specif-icity (%)	Error
493 (all shocked)	4741	1461	33	3161	86	94.4	99	AED
400 (200 shocked)	4154	562	12	3460	120	82.4	99.7	AED+ Crew

Table 1. - Analysis of ECG rhythm strips in two populations

The ECG rhythm strips in two patient populations were analysed to determine the ability of the AED and ambulance crews to detect a shockable rhythm and to initiate appropriate defibrillation. Table 1 shows the results of this analysis. Note that analyses are based on the 3 second rhythm strips and not on the patient's whole ECG, so that although all the patients in the first group were shocked there were still true negatives and false negatives detected on some of the 3s strips within their ECGs. Only 66 of the 120 false negatives in the second population were attributable to the AED, giving a sensitivity of 90.3% for the AED. The sensitivity of the AED is dependent on the prevalence of shockable rhythms, but will be within the range 90.3-94.4% for most emergency medical services[15].

2.2 Initial Experience

During the first year of the study (October 1988- October 1989) 6706 forms were collected from across Scotland [7]. Of these, 1111 were cardiac arrests and patients were defibrillated in 602 of those cases. 75 out of the 602 (12.5%) were discharged from hospital alive. The rest were forms completed solely for monitoring purposes.

Assuming that forms were filled in for all events (a very optimistic assumption) these figures suggest that arrests occur in 17% of cases where monitoring criteria are fulfilled. If this is the case there is very strong argument to suggest that ambulances should be called upon the onset of chest pain. The basis for the argument is that an arrest occurring in the presence of an ambulance crew has a significantly higher success rate than an arrest occurring before crew arrival[16]. If the patient or relative contacts the emergency services on the onset of chest pain then the probability of the crew being on the scene when the arrest occurs will be higher. This issue is relatively controversial. Should the general public be encouraged to call '999' instead of their General Practitioners (GPs) with the onset of chest pain. There are few GP practices where a GP can respond faster than

an ambulance. Even if the GP does arrive faster it is unlikely that they will carry a defibrillator. That is not to say that a GP should not be called to attend the scene.

The results from the first year of the study suggested that there was a need for improvement in the Scottish scheme when compared to other studies in other parts of the world [17]. It was necessary therefore that further auditing of the results be carried out and it was decided that a research assistant be employed to set up a database on which to store the study information and results. This would allow long term follow-up of individuals discharged from hospital alive following defibrillation. Once the data was on the computer, statistical analyses could be carried out periodically. The long term aim was to implement use of the database by the Scottish Ambulance Service themselves. The research assistant would be required to set up an appropriate computer application which could be used either on a regional level or centrally.

In 1990, a team of health professionals formed a task force and set out guide-lines for reporting on pre-hospital cardiac care[18]. A new form had to be designed so that the results of the study would be directly comparable with baseline data from other out of hospital resuscitation studies in other parts of the world. To do this, the original form had to be thoroughly dissected and a fault analysis carried out.

2.3 Fault Analysis of Original Heartstart Form (Pre May 1991)

By studying a large number of the forms certain flaws in the form's design became very obvious and patterns began to emerge. The lack of 'Don't Know' options on the forms meant that there was much missing data. Because the 'Don't Know' option was not available it was difficult to determine the difference between what the crews genuinely did not know and what they simply overlooked. Forms are often filled in very rapidly between emergency calls and it was perfectly feasible to assume therefore that questions had been genuinely overlooked. For this reason it was not correct to assume the negative when no answer had been provided. No analysis was carried out on fields, if no response was provided.

Patient status after the defibrillation event was often unclear from the forms. The Scottish Ambulance Service definition of a success was a patient having a spontaneous pulse on arrival at hospital. The study definition of success was a patient discharged alive from

hospital. If the patient did not have a pulse on arrival at hospital the crews often left the last section of the form blank which made hospital follow-up difficult.

Conclusions drawn from the old form were that it was too cluttered and that the flow of information was not logical. Many of the questions on the form were ambiguous in meaning, resulting in certain analyses being inaccurate. One of the most important factors influencing survival is whether or not the cardiac arrest is witnessed. Some crews took this to mean witnessed by themselves whereas others took it to mean witnessed by anyone. The number of events witnessed was therefore probably underestimated.

The question relating to cardiopulmonary resuscitation was also very ambiguous. It states 'CPR initiated within four minutes by ....'. If the question is taken literally it will not be filled in for cases of arrest where no one initiated CPR within 4 minutes. On the other hand, some crews would fill the section in for all cases so that it was evident that CPR had been initiated at some stage. One of the main areas of analysis in a study of this type is whether or not bystander CPR influences survival. From the data collected in the first two years it was impossible to analyse accurately the difference in survival in the four groups below.

1. Bystander CPR initiated immediately following arrest.
2. Bystander CPR initiated later than four minutes following arrest.
3. Ambulance Crew witness arrest and immediately initiate CPR.
4. Bystander witnesses arrest but does nothing. Crew initiate CPR on arrival.

In other parts of the world it has been shown that immediate CPR by a bystander witnessing the cardiac arrest has a significant impact on the survival of the patient[11].

Ascertaining whether or not the patient was actually shocked was impossible in some cases, where the crew indicated that 'Defibrillation was initiated' but there was no mention of a shock and no accompanying printout. This was the case for approximately 4% of patients. It is probably the case that these patients were not shocked and that the crew misinterpreted the question as meaning 'Were defibrillation pads used?'.

2.4 Practical Problems with Data Collection

When a crew has just attended a serious incident such as a road traffic accident, a house fire or a cardiac arrest the one thing that they want to do is wind down and forget about

what they have just been through. For the duration of the event they have been solely concerned with the welfare of the patient and the skills they have had to use . It is very difficult for them to turn their attentions to collecting patient details, unimportant to them, such as patient date of birth, address and postcode. Even more of a problem is the retention of timings, time of arrest, time CPR initiated etc.

The amount of paper-work that ambulance crews have to cope with now is phenomenal. They have to fill in a log sheet for each event with details of patient identification, nature of incident and timings. In addition to this there are now other forms for various on-going studies. Paramedics have to fill in a detailed event form describing the incident and listing drugs administered and skills used. In 1992 a standard patient report form was introduced for completion after every event (appendix 3). Crews are concerned that the care of the patient is taking a back seat This attitude is understandable and problems of this nature cannot be overlooked. They are in many ways more important than those of form design and wording of questions because without the support of the crews there would be no study. This fact was overlooked in the first couple of years of the study. The crucial component is feedback. If the crews feel that the forms are being read and the analysis is of use they will be more inclined to co-operate.

2.5 Methods of Patient Follow-up

The first stage in the follow-up process was to establish whether the patient was transported to hospital or not. It was decided that no mention of a receiving hospital on the form indicated that the patient was deceased and was left at the scene of the arrest or transported to the mortuary.

Where a patient was transported to hospital and there was no indication of whether the patient was dead on arrival or died subsequently in the Accident and Emergency Department a patient follow-up form was sent to the relevant medical records department. It was then up to the medical records department to trace the patient on their medical records computer system or via the A&E Department. Once traced the patients full details (i.e. Full name, Date of Birth, GP etc.) were completed on the form. If the patient was admitted to a ward a discharge summary was sent to me by the medical records department. In many cases case notes were missing or elsewhere in the hospital when the request was made. It was necessary in these cases to send a further request for a discharge summary to either the patient's General Practitioner or their consultant during their stay in hospital.

Sometimes the patient could not be traced at all, for the following reasons:-

1. Insufficient details on Cardiac Report Form.
2. Incorrect details on Cardiac Report Form (e.g. incorrect episode date)
3. No record of patient on A&E register.
4. No record on the medical records computer system.
   i.e. These systems are fallible, as a name spelt incorrectly when first entered means that unless the name is spelt incorrectly when follow-up occurs then the computer will not register the request as being for the same patient.

Where no trace of the patient could be made (approximately 1% of cases) it was decided to exclude the patient for purposes of analysis. It was unfair to assume that the patient was dead as some of the no trace patients were said to have a pulse on arrival. There have been cases where patients have been discharged alive from hospital after having no pulse on arrival at A&E.

The two categories 'dead on arrival' and 'died in A&E' were merged as the outcome could depend on specific hospital policies (i.e. one might make a resuscitation attempt and the another certify death on arrival at hospital). Clinical analysis would therefore only be carried out for those patients admitted to a ward.

2.6 The New Cardiopulmonary Resuscitation Report Form

In the first instance, what was required was a form that was much clearer and easier to fill in. This would unfortunately mean that the form would have to extend beyond one page, something the ambulance crews would not appreciate. To ensure clarity, easy data entry and analysis it was decided to use as much space as was required on the basis that the amount of information requested was still comparable with that on the old form. After filling in one or two of the new forms the crews would realise that the forms were in fact easier to complete. The other main decision that was taken at this time was to cease collecting forms used for monitoring purposes only. This would cut down the crews work load considerably as a high percentage of emergency calls are for chest pain where no collapse occurs.

Previously analysis had only been carried out for defibrillation events. In order to compare the 'Heartstart Scotland' results to similar studies world-wide it was necessary to start collecting forms for all cardiac arrests where a resuscitation attempt was made (whether or not the patient is in a shockable rhythm) . This would allow closer scrutiny of GP and bystander behaviour when encountering a case of out of hospital cardiac arrest. It also meant that extra statistics could be gathered such as percentage of cardiac arrest patients in shockable and non-shockable rhythms.

Collection of printouts was of utmost importance in order to determine the rhythm the patients heart was in at the time the crew arrived. The printouts also confirm the timings of time of first and subsequent shocks. Emphasis would therefore have to be made on the new form that the printout was essential. In the first two years some areas were particularly bad at collecting printouts. The main problems being printers constantly breaking down, accident and emergency consultants keeping printouts and crews failing to download the medical control module before they went off shift. Of the 75 survivors from the first year less than 50% had printouts to accompany the forms. There was therefore no way of analysing whether the defibrillator had shocked the correct rhythm. There is some doubt as to whether 3 of the 75 patients actually sustained any shocks at all.

The plan was to set up a series of forms based on a unique patient numbering system to ensure a clear flow of information. Whereas before, forms had been numbered after they had been filled in and collected, the new ones would be numbered before being distributed, to cut out the possibility of human error (for example, assigning more that one patient the same number). District Ambulance Officers would have to read over the forms, check them and sign them. This would hopefully mean that the crews would take more care in filling in the forms as they would know that a formal audit was being carried out.

A paper of recommended guide-lines was published in August' 91[18]. The paper set out a uniform pattern for reporting results of out-of -hospital cardiac arrest. These guide-lines meant that the results of studies across the international spectrum could be compared. The methods of reporting were decided by members of various international heart organisations at a meeting in Utstein Abbey, located on a small island near Stavanger, Norway. Participants discussed the widespread problems of nomenclature and lack of standardisation in reporting. The recommendations were titled 'The Utstein Style'.

A template was designed (figure 8), for direct comparability and there were specific definitions outlined for time points, time intervals, definitions of clinical items and

outcomes. Recommendations for describing the emergency medical resuscitation system were also outlined.

The results of the second year of the Heartstart Scotland study (still based on the old report form) were reported[16] in 'Resuscitation' and complied as far as possible with the Utstein style.

2.6.1 The Computer Database

All data entry in the first year was carried out by Janice Watson (Research Assistant, Department of Medical Cardiology, GRI). When Janice received the forms they had already been prepared and numbered with a unique six digit code by Mary Redmond (Research Nurse working for the ambulance service). All the data collected were entered onto a Paradox Database. Paradox is a menu driven relational database. The 602 forms from the first year of the study were entered onto a set of tables linked by their six digit serial number. All 602 patients received one or more defibrillatory shocks. The forms were entered onto the database, and subsequently analysed using the BMDP statistical package. Mary Redmond carried out the calculations for the non-defibrillated patients herself and these data were not entered onto the computer database.

To ease patient follow-up, when the second year's forms started to arrive, some of the tables on the database were edited to cope with all 3 form formats. Paradox forms and reports were developed for ease of data management. Reports were generated for "flagging" patients with the Registrar General's office in Edinburgh, tracking patients in medical records departments and writing to crews when patients they had resuscitated were discharged alive . Any database forms designed were made to tie in (as far as possible) with the hard copies for ease of data entry.

2.6.1.1 New Heartstart Form

The new form was designed on Microsoft Word version 2. It extends to four pages and has been revised once since its inception in Spring 1991. The most recent version can be seen in appendix 4. The forms are printed by a Glasgow print firm on thin coloured card, to improve durability and to prevent photocopying by ambulance crews. Both versions of the form are different colours for easy identification. An instruction booklet (condensed form, appendix 5) was designed to help the ambulance crews understand the new form and to

solve any problems they encountered when completing it. The second version of the form included more details about Bystander CPR and personnel present at the scene of the arrest. The serial numbers are stamped onto the forms before they are dispatched to the various ambulance area. The first digit of the serial number identifies the area.

All data entry is now carried out at the Database Unit, University of Glasgow. The forms are batched according to area and form type before being transferred across to the University for data entry. Two new Paradox tables have been set up, one for each version of the form. Error files are also generated detailing data entry problems. Once the forms and the error files have been returned to Glasgow Royal Infirmary (GRI) follow-up can proceed and the database can be updated to correct any serious errors.

CHAPTER 3

The Heartstart Scotland Population

3.1 Demographic Statistics

The population of Scotland in 1990 was 5,102,400 comprising 2,466,795 males and 2,635,605 females[19]. The population split by age groups is shown in table 2: In 1991 there were 61,041 deaths in Scotland of which 16,855 (27.6%) were due to Ischaemic Heart Disease (international classification of disease (ICD) codes 410-414). The Utstein guidelines[18] require ICD codes 410-414 mortality statistics for the 55-64 age group as a means of international comparison. 1617 of the Ischaemic Heart Disease (IHD) deaths in Scotland in 1991 were Males age 55-64 years and 725 IHD deaths were females in the same age group.

Age Group	Population
0-12 months	63,703
1-4 years	262,191
5-14 years	631,314
15-24 years	775,443
25-34 years	799,611
35-44 years	691,978
45-54 years	578,683
55-64 years	538,078
65-74 years	433,460
75-84 years	261,047
85+ years	66,892

Table 2. : Scottish population (1990), by age

From October 1988 to March 1993 data on 5361 cardiac arrests had been entered onto the Paradox database. The median patient age was 65 years (range 0-96 years, inter quartile range (IQR) 57-72 years, n=5260), and the population consisted of 71% (3804) males

(n=5348). The point estimate for the median age difference between males and females is 4 years , 95% CI, [3years, 5years] (table 3). Age distributions for males and females are shown in figure 7 .

	Number	Median (years)	Range (years)	IQR (years)
Males	3731	65	0-93	55-71
Females	1520	68	0-96	59-75

Mann-Whitney test for difference in medians, p<0.0001.

Table 3 - Difference in age by gender

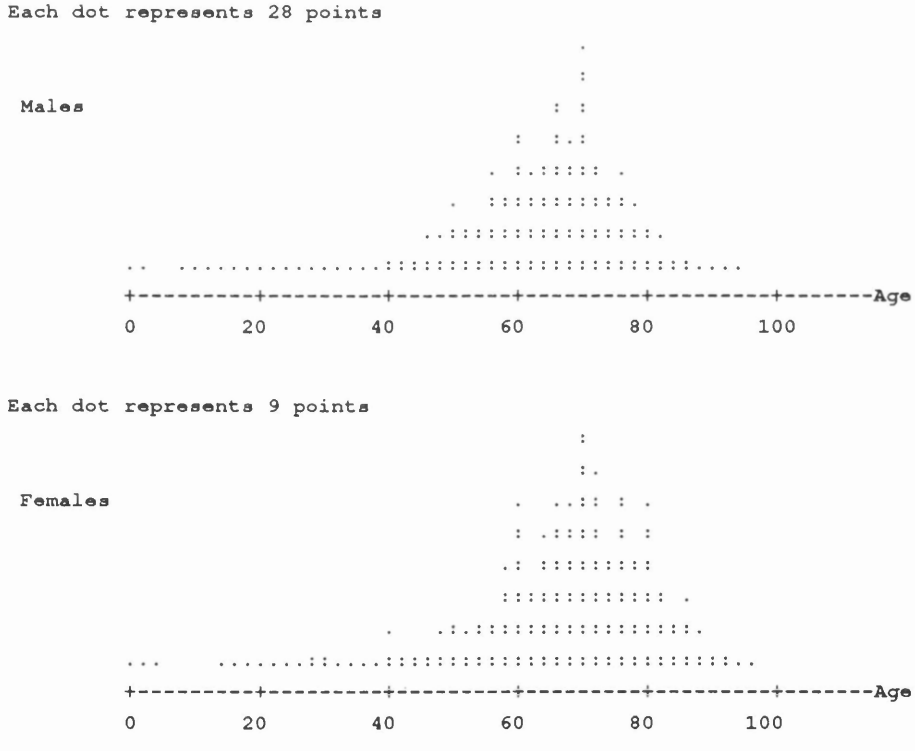

figure 7 - Age distributions for males and females

3.1.1 Previous History and Cause of Cardiac Arrest

The Utstein guidelines require analysis only of patients who arrest due to a cardiac cause. Unfortunately the forms completed prior to May 1991 did not enquire as to the cause of arrest. From more recent data (August 1994) we can estimate that 67-81% of arrests were due to a cardiac cause (67% cardiac, 14% unknown). Incidence of a Previous Myocardial Infarction or Previous Angina was recorded. Patients were reported to have had a previous myocardial infarction in 17% (933) of cases and previous angina in 17% (929) of cases . For the Glasgow MONICA project, all cardiac events (in and out of hospital) in the North Glasgow area are recorded from GP notes, hospital admissions, ambulance logs and patient interviews. These more complete records (personal communication - Dr. Caroline Morrison), suggest that 25% of all cardiac arrest patients had a previous myocardial infarction and 33% had previous angina. A patient history can only be obtained if there are friends or relations of the patient at the scene of the arrest, and even then only if their emotional state allows them to recall such details. Our figures are therefore likely to be lower than the true Scottish values due to under reporting.

3.1.2 Timings

In cases where a patient arrested before an ambulance was called, the median delay from arrest to '999' call was 3 minutes (range 0-591 minutes, IQR 1-7 minutes, n=2095). Unfortunately time of cardiac arrest was often a best estimate from the ambulance crew based on interviews with bystanders at the scene. Sometimes the arrest time recorded might relate to the last time the patient was seen alive, thus the 591 minute delay above. By definition arrest times should only be known for witnessed arrests but guess-timates for a small group of unwitnessed arrests were also included in the analysis (due to the ambiguity of the question as explained in section 2.3).

The median ambulance response time was 7 minutes (range 0-116 minutes[c] , IQR 5-10 minutes, n=5048) for Scotland as a whole. Response times were not found to be dependent on type of region e.g.. rural, urban. Where a patient was transported from the scene of the arrest to a hospital emergency department (n=3397), median journey time was 7 minutes (range 0-120 minutes, IQR 4-11 minutes).

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[c] 116 minutes seems like a very long response time, but it should be noted that not all calls were on the '999' system, some were GP 'Urgent' calls

3.1.3 Factors Affecting Survival

Factors thought to influence survival to hospital discharge are ;

- whether the arrest was witnessed
- whether the patient received bystander CPR
- whether the patient experienced chest pain prior to the arrest
- whether the patient was in a shockable rhythm and if so how many shocks were delivered
- the initial outcome (pulse on arrival at hospital Accident and Emergency department) of the resuscitation attempt.

Overall 54% (2874) of all arrests were witnessed (either seen or heard) by bystanders (excluding ambulance crews) at the scene. Ambulance crews witnessed 12% (623) of all arrests. Bystander CPR was started in 38% (1792) of all arrests occurring before the arrival of an ambulance crew (n=4738). 1125 (21%) patients were reported to have had chest pain prior to the cardiac arrest. As previously explained, this figure is likely to be an under estimate of the true number of patients suffering chest pain prior to their arrest.

A shockable rhythm (figure 6) was present in 66% (3545) of arrests . In this group the median number of shocks given was 3 shocks (range 1-19 shocks, IQR 1-5 shocks, n=3473), and the median arrest to first shock time was 11 minutes (range 0-30[d] minutes, IQR 6-16 minutes, n=1885).

[d]I used 30 minutes as a cut off point as it is highly unlikely that a patient would be in a treatable rhythm more than 30 minutes following a cardiac arrest.

CHAPTER 4

The Chain of Events from Onset of Symptoms to Hospital Discharge

Before embarking upon the survival analysis, we will take stock and review the system, in particular which external variables impact on the patients survival at various stages in the chain of events leading to death or hospital discharge.

4.1 Events from Cardiac Arrest to Hospital Admission

The task force of professionals who met at 'Utstein' abbey in Norway, presented their recommended guidelines for uniform reporting of out-of-hospital cardiac arrest in several different languages and medical journals in 1991[18].

A template approach to reporting data was recommended (figure 8). The denominator is all patients suffering a cardiac arrest with cardiac aetiology. This differs from the denominator in the Heartstart population, which is all cardiac arrests where a resuscitation attempt is made. As previously discussed, we did not collect data on arrest cause until May 1991. Any statistical analysis in this thesis is therefore based on the whole group. In addition we do not have access to police reports and post-mortem reports, so when arrest cause is requested on the current form, it is generally good guess work by the ambulance crew attending. In any future analysis for European or International presentation, data for obvious non-cardiac deaths such as trauma, drug overdose and drowning will be excluded.

The reporting template helps detect clinically interesting subsets of patients, at the different branch points. This information would be lost if only 'discharge alive' rates were reported.

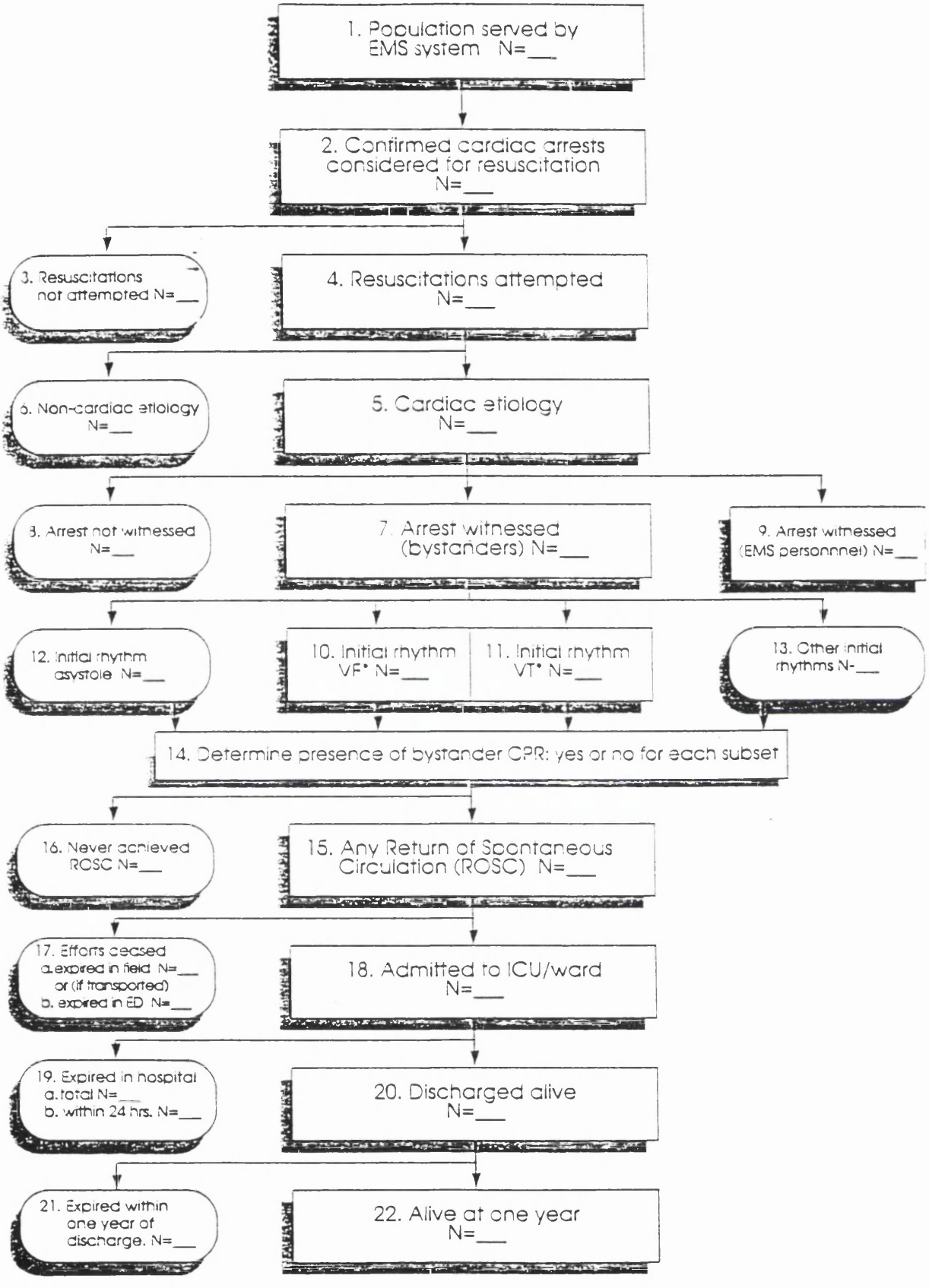

Figure 8 - Recommended 'Utstein' style template for reporting data on cardiac arrest

4.1.1 Time Points and Time Intervals

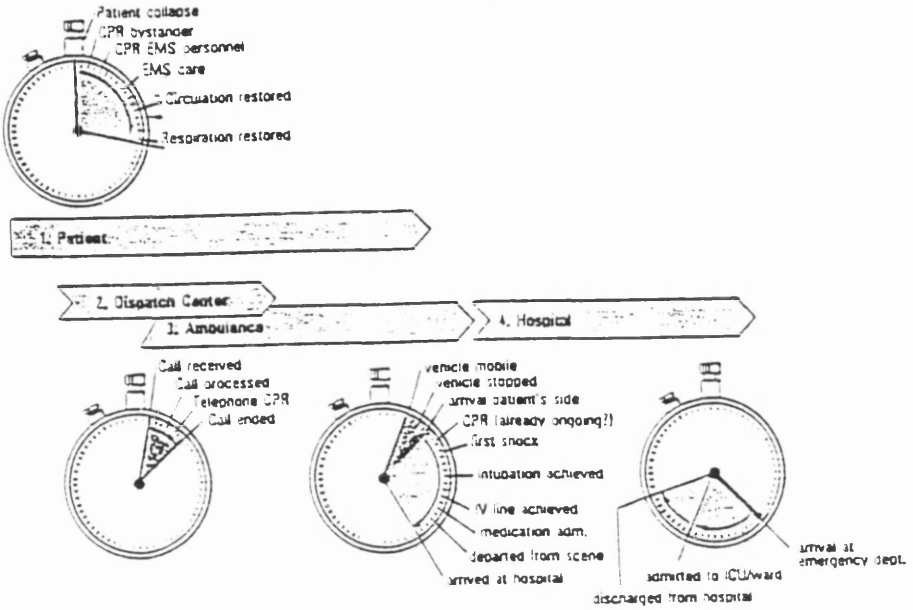

Figure 9 - Four clocks in cardiac arrest

All time intervals are defined in appendix 6. Delay until treatment determines the immediate, intermediate and overall outcomes in cardiac arrest. The most crucial time interval is the interval from patient collapse to initiation of resuscitation, whether this be by a bystander or EMS personnel. This interval has been demonstrated to be the major determinant of ultimate survival. There are four important 'clocks' in cardiac arrest. These are the patient clock, the dispatch centre clock, the ambulance clock and the hospital clock. Figure 9 shows the four clocks of sudden cardiac arrest as presented in the guidelines. Three important stages in the resuscitation process are :-

- whether the patient is in VF in the presence of the ambulance crew
- whether the patient is admitted to a hospital ward
- whether the patient is discharged alive

4.1.2 Circumstances Surrounding Cardiac Arrest

The 'Utstein' template (figure 8) separates the arrest types into three groups :-

- arrest not witnessed
- arrest witnessed by a bystander
- arrest witnessed by EMS personnel

For our purposes there are two mutually exclusive types of out-of hospital cardiac arrests. These are :-

- The crew witnessed arrest where the patient arrests in the presence of the ambulance crew
- The arrest where the patient is in a collapsed state when the ambulance crew arrive on the scene

4.1.2.1 Crew Witnessed Arrests

Arrests witnessed by the ambulance crew themselves represent a unique subset of all arrests for the following reasons.

- The patient has a higher probability of being in VF when recently arrested, as VF is a rhythm that deteriorates to asystole over time.
- If the patient is in VF the crew are capable of administering a shock within minutes, sometimes seconds of the arrest.
- The patient's brain does not have a lack of oxygen supply subsequent to the arrest as ventilation is commenced instantly by the crew.

All these factors result in high success rates within this group. The variables response time, bystander CPR (Y/N), arrest witnessed (Y/N) become redundant. In any regression analysis therefore ,crew witnessed arrests are excluded. This scenario is the optimum for the patient's survival and success rates compare with those for in-hospital arrests.

4.1.2.2 Non Crew Witnessed Arrests

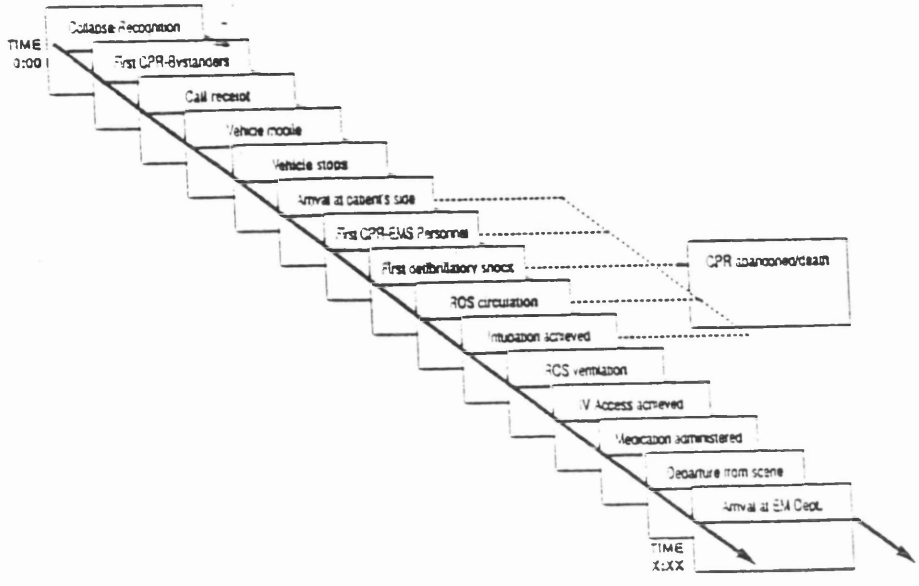

Figure 10 - Events associated with a cardiac arrest occurring before '999' call is made

There are 4 possible scenarios if the patient arrests before the arrival of the crew. These are:-

- Patient collapse witnessed by bystander, '999' call (figure 10)
- Patient collapse unwitnessed, '999' call
- symptoms present, '999' call, patient collapse witnessed by bystander
- symptoms present, '999' call, patient collapse unwitnessed.

In all four scenarios the crucial variable is whether or not Bystander CPR was administered and how soon after the arrest it occurred. Time from collapse to arrival of the ambulance crew is crucial to patient survival. Unfortunately, time of collapse is the biggest source of missing data.

4.2. Events after Hospital Admission

In Scotland there are three distinct type of hospital :-

- Teaching hospitals (Such as Glasgow Royal Infirmary or Edinburgh Royal Infirmary)
- District general hospitals (Such as Royal Alexandra Hospital, Paisley or Hairmyers Hospital, East Kilbride)
- Community hospitals (Such as Western Isles Hospital or Dr. Gray's Hospital, Elgin)

The majority of patients are admitted to teaching hospitals or district general hospitals where optimum care is generally available. Patients admitted to community hospitals are often transferred to a larger hospital immediately from the accident and emergency department or within a few days of admission. In unusual cases (e.g. young patients with rare cardiac conditions) patients are moved from district generals to teaching hospitals for specialist care.

Once discharged from the accident and emergency department, cardiac arrest patients are generally admitted to one of three types of ward:-

- General medical ward (the only type of ward community hospitals have)
- Coronary care unit
- Intensive care unit

Patients not requiring ventilation support are normally admitted to general medical or coronary care ward, whereas patients requiring ventilation support are admitted to intensive care units. Many hospitals combine their coronary care ward with intensive care.

Unfortunately the in-hospital data collected for the Heartstart analysis are limited. It would have been too difficulty to access such a large number of case notes from hospitals across Scotland. Had I been able to acquire them, Professor Cobbe would not have had the time to review them all to the required level of detail.

In-hospital data collected comprised of length of stay, patient age, patient gender and thrombolytic therapy on admission (see section 6.4.1.2). Hospital discharge summaries were also reviewed to assess the patients neurological status, diagnosis and proposed therapy on discharge.

CHAPTER 5

Initial Survival from Out-of-Hospital Cardiac Arrest

5.1 Logistic Regression

The database includes many variables that may or may not influence a patient surviving a resuscitation attempt. Each combination of different levels of these variables defines a category for which an estimate of the probability of survival can be made[20], e.g. a 60 year old male with no history of heart disease, given bystander CPR and shocked 3 times. Although data on 5000 patients may be perfectly adequate for assessing the relative risks associated with a few discrete levels of a single factor, it is insufficient to provide separate estimators for the large number of categories generated by combining even a few more or less continuous factors.

By developing a mathematical model to calculate smoothed estimates we can predict the risk even for categories in which scant information is available. Such a model is the linear logistic model. The logit transform of the survival probability in each risk category is expressed as a linear function of regression variables whose values correspond to the levels of exposure to the risk factors. If P denotes the probability of not surviving the resuscitation attempt, the logit transform, y, is defined by :-

$$y = \text{logit}\, P = \log\left(\frac{P}{1-P}\right)$$

or conversely expressing P in terms of y:-

$$P = \frac{\exp(y)}{1+\exp(y)}$$

5.1.1 Logistic Regression in a 2x2 Table

The simplest example of logistic regression is provided by a 2x2 table. Take the following example :-

	No Bys. CPR	Bys. CPR	Total
Died	2801	1610	4411
Discharged alive	185	168	353
Total	2986	1778	4764

The estimated odds ratio :-

$$\hat{\psi} = \frac{P_1 Q_0}{P_0 Q_1} = \frac{(2801/4411)*(168/353)}{(185/353)*(1610/4411)} = \frac{2801*168}{1610*185} = 1.58$$

indicates that the odds of a dead patient having received no CPR at the scene of the arrest are 1.58 times those for a surviving patient.

The 95% confidence limits for the odds ratios are calculated using Miettinen's (1976) test based method.

i.e. $\psi_U, \psi_L = \hat{\psi}^{(1 \pm 1.96/\sqrt{\chi^2})}$

where $\hat{\psi}$ is the estimated odds ratio and χ^2 is the calculated chi-squared statistic for the 2x2 table.

The estimated log odds ratio may be expressed :

$$\hat{\beta} = \log \hat{\psi} = \text{logit}P_1 - \text{logit}P_0 = 0.457$$

as the difference between the two logits. Let us define a single binary regression variable x by x=1 for no CPR and x=0 for CPR.

If we write P(x) for the probability of a dead patient having received no CPR at the scene of the arrest and :-

$$r(x) = \frac{P(x)Q_0}{P_0Q(x)}$$

for the odds ratio, we have

$$\log r(x) = b(x) \text{ or } \text{logit}P(x) = \alpha + \beta x$$

where

$$\hat{\alpha} = \text{logit}\hat{P}_0 = 0.08$$

The relationship between the 2 parameters α and β in the model and the survival probabilities (P_1 and P_0) is such that :-

$$\hat{P}_1 = \frac{\exp(\hat{\alpha} + \hat{\beta})}{1 + \exp(\hat{\alpha} + \hat{\beta})} = 0.64$$

and

$$\hat{P}_0 = \frac{\exp\hat{\alpha}}{1 + \exp\hat{\alpha}} = 0.52$$

5.1.2 Design (Indicator) Variables

The regression approach is easily generalised to incorporate the effects of several risk factors at more than 2 levels. Suppose we take a factor such as age and split it into 3 levels. Two design variables are required. These might be coded as follows.

	Young	Middle aged	Old
x_2	0	1	0
x_3	1	0	0

In general, for a factor with K levels, K-1 design variables are needed to describe its effects.

5.1.3 General Definition

The model relates a dichotomous outcome variable y which in this context denotes whether (y=1) or not (y=0) the patient dies as a result of a resuscitation attempt, to a series of k regression variables, $\mathbf{x}=(\mathbf{x}_1,\ldots,\mathbf{x}_k)$

$$P(y=1|\mathbf{x})=\frac{\exp(\alpha+\Sigma\beta_k\mathbf{x}_k)}{1+\exp(\alpha+\Sigma\beta_k\mathbf{x}_k)}$$

or equivalently :-

$$\text{logit}P(y=1|\mathbf{x})=\alpha+\sum_{k=1}^{K}\beta_k\mathbf{x}_k$$

This formulation implies that the odds ratio (OR) for individuals having two different sets $\mathbf{x}^*$ and $\mathbf{x}$ of risk variables is:-

$$OR=\frac{P(\mathbf{x}^*)\{1-P(\mathbf{x})\}}{P(\mathbf{x})\{1-P(\mathbf{x}^*)\}}=\exp\{\Sigma\beta_k(\mathbf{x}_k^*-\mathbf{x}_k)\}$$

So α represents the log odds of survival risk for a person with a standard set of regression ($\mathbf{x}$=0) variables while exp.(β_k) is the fraction by which the log OR is increased (or decreased) for every unit change in x_k. A large number of possible relationships may be represented in this form by including among the x's indicator variables and continuous measurements, transformation of such measurements and interaction variables.

Logistic regression is a useful technique where multivariate normality of all variables in the regression equation cannot be assumed, and use of linear regression techniques is incorrect. The BMDP program LR is used to carry out the analysis[21]. The program uses a stepwise approach. At each step one of the variables x_k is added or removed from the model. Interactions can be entered into the model and stepping can be controlled or negated. Interactions can only be entered into the model if the main effects and lower order interactions have already been entered.

For the subset of patients for whom complete data were available, stepwise logistic regression analysis was used to investigate

a) predictors of whether or not patient will be in Ventricular Fibrillation when the ambulance crew arrive.

b) predictors of outcome following defibrillation.
   - to a ward
   - to discharge (if admitted to a ward)

The presentation of the models is in the form of tables derived from the BMDP output. For this reason continuous variables are presented as means and standard deviations. I accept that medians and ranges (as presented in Chapter 3) might be more appropriate for certain variables such as 'number of shocks'.

5.1.4 Results of Two Recent Studies

Studies of the outcome from out-of-hospital cardiac arrest includes work by Weaver in Seattle[22] and Becker in Chicago[23].

In Seattle[22], data were analysed for 285 patients who suffered a witnessed VF arrest and for whom full details were available. In the Seattle system the fire brigade are the first responders (response times 3.1±1.5 minutes, mean ± standard deviation), with the paramedic fire fighters responding as required (6.2±3.2 minutes). The survival rates were modelled for each time delay using a logistic regression model . Where P(x) is the probability of being discharged alive following the resuscitation attempt and collapse to first DC shock is denoted by DS, the fitted model is :-

$$\text{logit}(P(\mathbf{x})) = 2.93 - 0.02age - 0.1593DS$$

It is unclear from the paper whether or not the variables were selected on a stepwise basis.

In Chicago[23], the emphasis was on survival in relation to race (i.e. black vs. white). The conclusion reached was that the black community in Chicago are at a higher risk for cardiac arrest and subsequent death than the white community, even after controlling for other variables such as age. Chicago has approximately 2.7 million inhabitants in an area of 590km^2. The study period was two years, January 1st 1987 to December 31st 1988. The authors excluded 499 cases due to incomplete data, making the study population comprise

6451 patients: 3207 whites, 2910 blacks and 334 persons of other races .Only non-traumatic cardiac arrests were included .The eight predictor variables included in the model were race, sex, age, paramedic witnessed (Y/N), bystander witnessed (Y/N), bystander CPR (Y/N), initial cardiac rhythm and ambulance response time. The first order interactions were also included, although there is no mention of them apart from in the statistical analysis methods section. To determine the effect of the eight risk factors on survival , the authors graphically presented the odds ratios (and 95% confidence intervals) of the variables as calculated in the logistic regression model (no listing of the parameter estimates is provided). Sex was included in the model as it is used as a common predictor of mortality. The other six variables were included in the model on the basis of their documented effect on survival rate. Outcome variables were successful hospital admission and survival to discharge (given hospital admission).

5.1.5 Analysis of 623 Crew Witnessed Arrests in the Heartstart Study

As previously discussed, crew witnessed arrests were excluded from my stepwise analyses due to their extremely high success rate[16] and the fact that they confound other factors to be included in the model such as 'bystander CPR' and 'arrest witnessed'. i.e. A patient arresting in the presence of an ambulance crew will never receive CPR from a bystander .

During the Heartstart study period there were 623 traced crew witnessed arrests. In total 164 (26%) patients were discharged alive, a considerably higher success rate than for the population as a whole. The median age in this population is 66 years, male female ratio 2.3:1. 56% of patients were known to have experienced chest pain prior to their arrest. This proportion is higher than the population as a whole because it was probably the warning of chest pain that led them to call the ambulance and therefore have the crew attending when the arrest occurred. Analysis of arrest to first shock time and number of shocks (table 4) reveals lower arrest to shock times and a smaller median number of shocks than the whole population. A break down of the success rates in crew witnessed arrests is shown in table 5.

Variable	Median	Inter-quartile range
Arrest to first shock time	2 mins	1-4 mins
number of shocks	2 shocks	1-3 shocks

Table 4 -Arrest to shock times and number of shocks in crew witnessed arrests

	n	% survival (of shocked patients)
crew witnessed arrests	623	-
patients shocked	441	-
admitted hospital	204	46.26
discharged alive	160	36.28

Table 5 -Success rates in crew witnessed arrests

5.2 Predicting the Presence of a Shockable Rhythm

One of the critical factors in determining the final outcome of the patient is whether or not the patient is in ventricular fibrillation at the time of on scene arrival of the ambulance crew. Factors thought to influence the patients cardiac rhythm when the ambulance crew arrive were analysed using the χ^2 statistic and odds ratios (and 95% CI). Data were available on 4738 patients. Results are presented in table 6 and graphically in figure 11.

The four factors that most significantly improve the patient's odds of being in a shockable rhythm are a witnessed arrest, bystander CPR, chest pain prior to collapse and a fast response time. To a lesser extent male gender and a history of heart attack appear to improve the patients odds of being in VF.

Factor	a/(a+c)	b/(b+d)	χ^2	Odds Ratio	95% CI
Bystander CPR	1295/1727	1508/2569	120.80	2.11	1.85,2.41
Arrest Witnessed	2120/2850	664/1266	192.73	2.63	2.29,3.01
Response Time <=5mins	1134/1561	1750/2857	57.81	1.68	1.47,1.92
Patient <= 65 years	1576/2338	1459/2254	3.67	1.13	0.997,1.28
Male	2275/3340	820/1332	18.28	1.33	1.17,1.52
History of MI	518/786	675/1184	15.64	1.46	1.21,1.76
Chest Pain	606/806	712/1128	31.53	1.77	1.45,2.16

Where :-

	Factor (yes)	Factor (no)
Defibrillated	a	b
Not Defibrillated	c	d

Table 6 - χ^2 statistics and odds ratios (and 95% CI) for factors affecting probability of patient being defibrillated

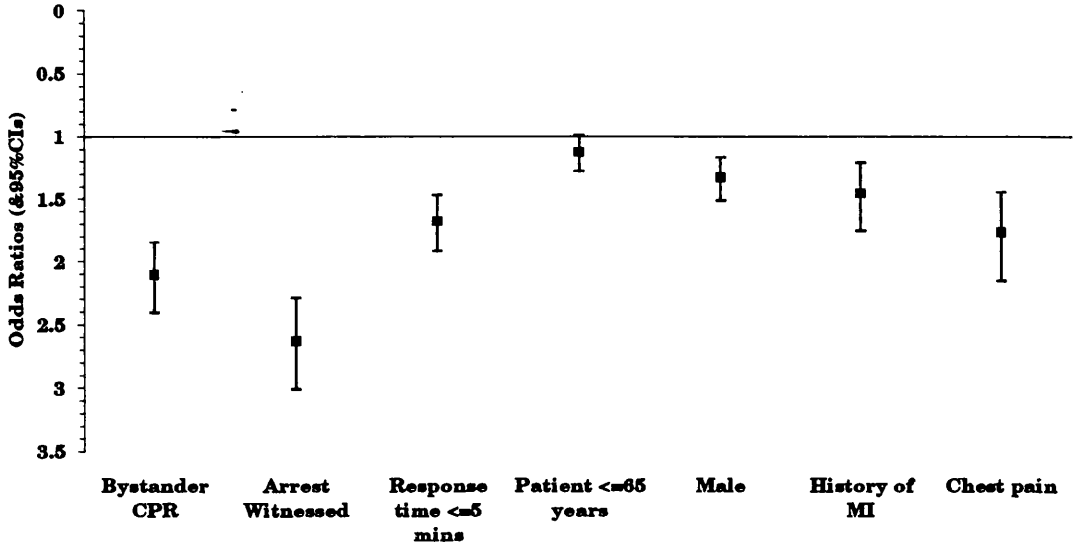

Figure 11 - Odds ratios and 95% confidence intervals for factors affecting probability of patient being defibrillated

5.2.1 Stepwise Regression of Patient Shocked vs. Patient Not Shocked

All the variables were entered into the model based on the default criteria used by the BMDP program (remove limit=0.15, enter limit=0.10). The dependent variable is whether or not the patient was defibrillated. Predictors included in the regression model were gender , patient age, arrest witnessed (Y/N), response time, bystander CPR (Y/N) (table 7). Previous MI (Y/N) was not included as insufficient data was available. Chest pain (Y/N) was excluded for the same reason. Crew witnessed arrests were excluded from the analysis. Data were available for 3578 cases.

Variable	Mean	Standard deviation
Age of patient	63.2 years	14.16 years
Response time	7.69 minutes	4.84 minutes

Variable	Category	Frequency	Design Variable
Gender	Male	2565	1
	Female	1013	0
Arrest Witnessed	Yes	2510	1
	No	1068	0
Bystander CPR	Yes	1443	1
	No	2135	0

Table 7- Description of variables in shocked/not shocked regression model

Variable	P-value
Arrest Witnessed	< 0.0001
Bystander CPR	< 0.0001
Response time	< 0.0001
Gender	< 0.0001
Age	0.2702

Table 8 - Initial p-values to enter the shocked/not shocked model

Variable	P-value
Arrest Witnessed	< 0.0001
Bystander CPR	< 0.0001
Response time	< 0.0001
Gender	< 0.0001
Age	0.055

Table 9 - Order of entry into the shocked/not shocked model

Term	Exp.(Coef.)	95% Confidence limits
Gender	1.43	1.22 , 1.68
Arrest Witnessed	2.39	2.04 , 2.78
Age	1.00	1.00 , 1.01
Response time	0.935	0.92 , 0.951
Bystander CPR	1.94	1.66 , 2.27

Table 10 - Table of coefficients (and 95%CI) for shock/no shock model

The resulting logit model is :-

$$\text{logit}(P(\text{shock})) = -0.23 + 0.36\,Gender + 0.87\,Arrwit + 0.005\,Age - 0.067\,Response + 0.66\,BysCPR$$

where *Arrwit* = Arrest witnessed, *Response* = Response time,
BysCPR = Bystander CPR.

Age was not significant initially (table 8), but once all the other variables had been entered it satisfied the BMDP entry criteria and it was included (p=0.055) (table 9). The interpretation of the odds ratio i.e. that old age improves the chances of being in a shockable rhythm, is uncertain as p>0.05 and the confidence limits cover the value 1. All the parameter estimates and their 95% confidence limits are shown in table 10. The exp.(coef.) can be interpreted as the odds ratio for the binary variables, gender, arrest witnessed and bystander CPR. The odds ratios are presented graphically in figure 12. To make interpretation of the continuous variables more useful, age is presented as the impact of a 10 year difference and response time as the impact of a five minute difference (i.e. 0.935^5).

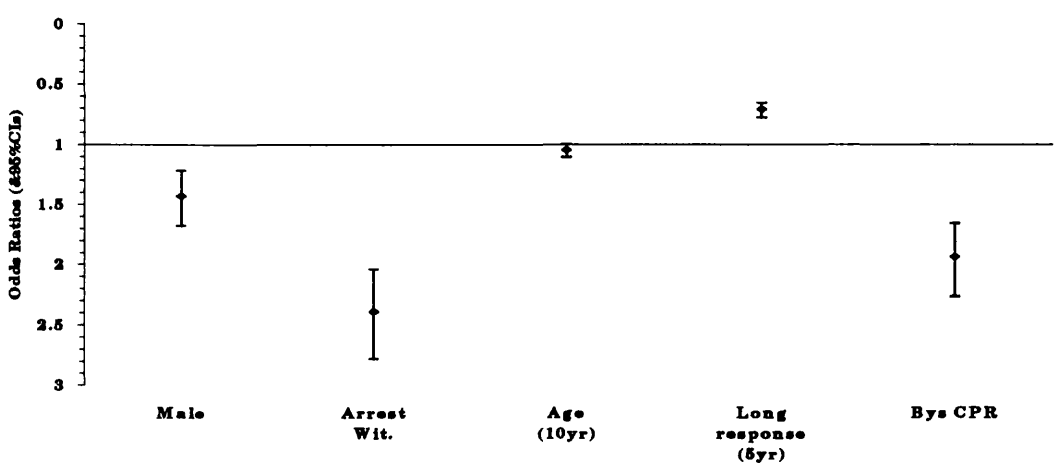

Figure 12 - Multivariate odds ratios for shock/no shock model

5.3 Predicting Admission to Hospital

It is possible that different factors affect admission to a hospital ward than those that influence whether or not the patient is discharged alive from hospital. The two possible outcomes, admitted to a ward and died prior to admission are defined :-

Died

Patient declared dead at the scene of the arrest, in the ambulance, or in the emergency department..

Admitted Hospital Ward

Patient admitted to a hospital ward (not A&E) following initially successful defibrillation.

Note that only defibrillated patients are included in this analysis as the prognosis in the unshocked group is so poor, and there are so few survivors to hospital admission (around 3%). There are 3104 cases for analysis. Results are presented in table 11 and graphically as odds ratios in figure 13. Interestingly male gender increases the odds of dying prior to admission as does younger age. Bystander CPR, witnessed arrest, short arrest to first shock time, a low number of shocks and short response time increase the odds of admission to a ward. History of MI and chest pain appear to have no effect at this stage in the analysis.

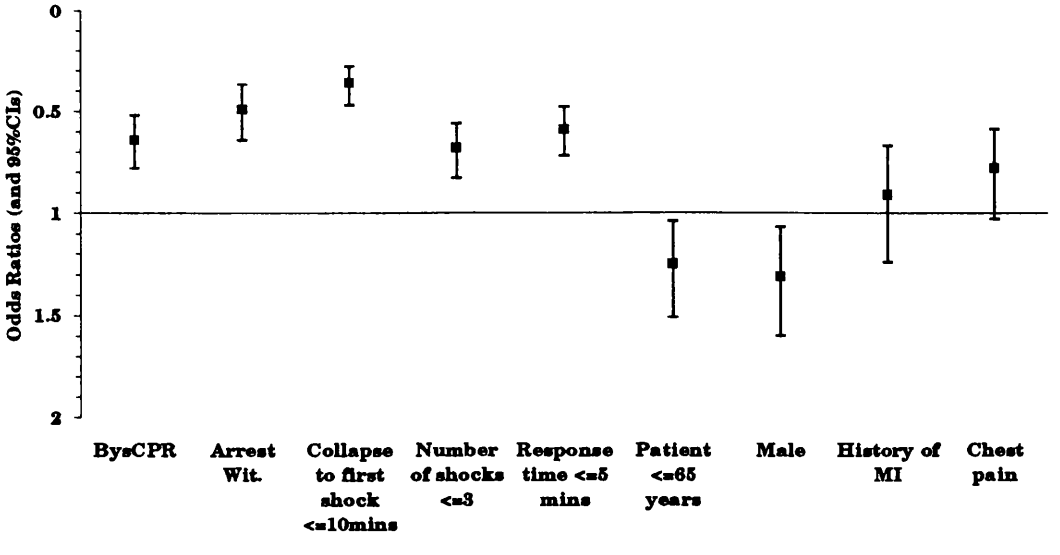

Figure 13 - Odds ratios and 95% confidence intervals for factors affecting probability of patient dying prior to ward admission

Factor	a/(a+c)	b/(b+d)	χ^2	Odds Ratio	95% CI
Bystander CPR	1031/1285	1298/1504	18.54	0.64	0.52,0.78
Arrest Witnessed	1703/2108	592/661	27.3	0.49	0.37,0.64
Collapse to first shock <=10mins	323/467	832/964	59.38	0.36	0.28,0.47
Number shocks <= 3 shocks	1508/1866	1001/1162	14.32	0.68	0.56,0.83
Response Time <=5mins	892/1128	1506/1741	27.49	0.59	0.48,0.72
Patient <= 65 years	1323/1568	1179/1453	5.54	1.25	1.04,1.51
Male	1904/2262	655/817	6.85	1.31	1.07,1.6
History of MI	423/514	561/671	0.35	0.91	0.67,1.24
Chest Pain	483/603	592/706	3.12	0.78	0.59,1.03

Where :-

	Factor (yes)	Factor (no)
Died	a	b
Admitted Ward	c	d

Table 11 - χ^2 statistics and odds ratios (and 95% CI) for factors affecting probability of patient dying prior to ward admission

5.3.2 Stepwise Regression of Hospital Admission

Only 'shocked' patients are included in this stepwise analysis. The variables number of shocks, age, arrest to first shock time and response time are treated as continuous. The BMDP generated results are summarised below (table 12). All the variables except 'arrest witnessed' are significant initially (table 13) and all the variables entered the model. The first variable entered into the stepwise model is arrest to first shock time, followed by number of shocks, gender, bystander CPR (Y/N), age, response time and arrest witnessed (Y/N) (table 14).

Variable	Mean	Standard deviation
Number of Shocks	3.88 shocks	3.03 shocks
Age of patient	63.22 years	12.53 years
Arrest-first shock time	15.21 minutes	8.81 minutes
Response time	7.11 minutes	3.92 minutes

Variable	Category	Frequency	Design Variable
Gender	Male	1017	1
	Female	350	0
Arrest Witnessed	Yes	1258	1
	No	109	0
Bystander CPR	Yes	677	1
	No	690	0

Table 12 - Description of variables in ward admission regression model

Variable	P-value
Arrest to first shock	0.0000
Bystander CPR	0.0051
Number of Shocks	0.0000
Gender	0.0085
Arrest Witnessed	0.2679
Age	0.0034
Response	0.0000

Table 13 - Initial p-values to enter the ward admission model

Variable	P-value
Arrest to first shock	0.0000
Bystander CPR	0.0003
Number of Shocks	0.0000
Gender	0.0024
Arrest Witnessed	0.0748
Age	0.0042
Response	0.0339

Table 14 - P-values at final stage in ward admission model

Term	Exp.(Coef.)	95% Confidence limits
Gender	1.64	1.2 , 2.25
Arrest witnessed	1.59	0.97 , 2.62
Number shocks	1.17	1.1, 1.24
Age	0.983	0.97, 0.995
Arrest to shock	1.07	1.04, 1.09
Response time	1.05	1.00, 1.10
Bystander CPR	0.58	0.43 , 0.78

Table 15 - Table of coefficients for ward admission model

The resulting logit of the model is :-

$$\text{logit}(P(\text{died})) = 0.29 + 0.50\,Gen + 0.46\,wit + 0.16\,sh - 0.018\,age + 0.066\,arsh + 0.048\,res - 0.54\,CPR$$

where Gen = Gender, $arsh$ = Arrest to first Shock time, wit=arrest witnessed, sh=number of shocks, $resp$=response time, CPR = Bystander CPR.

The parameter estimates and their 95% confidence limits are shown in table 15. None of the factors changes the odds to any great degree on its own. Of the binary variables bystander CPR and female gender are the most significant predictors of ward admission in terms of p-values.

The interpretation on the continuous variables depends on the units of measurement used. Arrest to first shock time, Number of shocks, age and response time all had $p<0.05$. Individually whether or not their impact on ward admission is important depends on the investigator's interpretation of the parameter estimates. The parameter estimate for a one year age increase suggests an association between increased age and ward admission. An increase of 10 years in age increases the patient's odds of admission by 19%. This would seem an unlikely situation in reality.

5.4 Predicting Survival to Hospital Discharge

The most important outcome variable following cardiac arrest is ultimate discharge from hospital. The two possible outcomes, discharged alive from hospital and died are defined :-

Died
Patient declared dead in the hospital ward following initially successful defibrillation.

Discharged alive
Patient discharged alive from hospital following initially successful defibrillation.

$\chi 2$ statistics and odds ratios for the various factors to be included in the model illustrated graphically in figure 14 and tabulated in table 16. These statistics are based on those patients that were admitted to a hospital ward (n=520).

From the patients' viewpoint, this is the most important stage in the system. Factors that improve the odds of discharge given that the patient has been admitted to a ward are bystander CPR, short arrest to first shock time, male gender, young age and chest pain prior to arrest. Previous MI increases the odds of the patient dying in the ward. The other factors appear to have little effect.

Factor	a/(a+c)	b/(b+d)	$\chi 2$	Odds Ratio	95% CI
Bystander CPR	106/254	129/206	19.86	0.43	0.30,0.62
Arrest Witnessed	200/405	40/69	1.74	0.71	0.43,1.18
Collapse to first shock <=10mins	16/42	131/234	4.58	0.48	0.25,0.94
Number shocks <= 3 shocks	176/358	87/161	1.06	0.82	0.56,1.20
Response Time <=5mins	117/236	128/235	1.13	0.82	0.57,1.18
Patient <= 65 years	107/245	156/274	9.10	0.59	0.42,0.83
Male	166/192	98/162	8.90	0.56	0.38,0.82
History of MI	55/91	49/110	5.04	1.90	1.08,3.33
Chest Pain	46/120	63/114	6.73	0.50	0.30,0.84

Where :-

	Factor (yes)	Factor (no)
Died	a	b
Discharged Alive	c	d

Table 16 - χ^2 statistics, and odds ratios (and 95% CI) for factors affecting probability of patient dying in ward

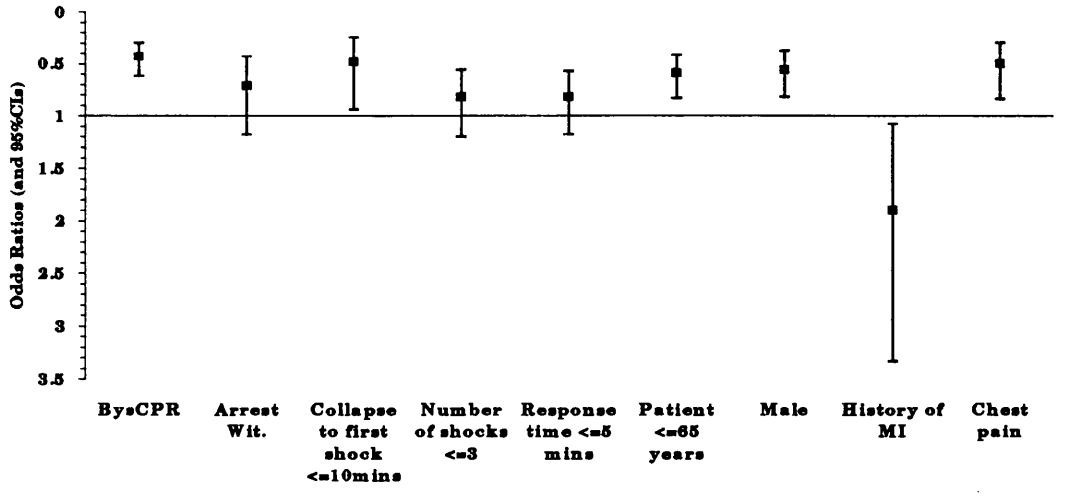

Figure 14 - Odds ratios and 95% confidence intervals for factors affecting probability of patient dying in ward

5.4.1 Stepwise Regression of Survival Status

Only patients who were defibrillated and admitted to a ward were included in the analysis. The variables included in the stepwise regression were gender, arrest witnessed by a bystander, number of shocks, age, arrest to first shock time, response time and bystander CPR started (table 17). Unfortunately the data on time of cardiac arrest was the main source of missing data for the whole population. It would not, however have been desirable to exclude arrest to first shock time from the analysis as it is the one of the most critical variables for survival. Complete data was therefore available for only 258 cases (139 died in ward, 119 discharged alive).

This is a more balanced model than the previous two in terms of proportion surviving. Computing time is also quicker due to both the high proportion surviving and a smaller total number of cases. For these reasons a more detailed analysis of these data will be carried out. Interactions among variables will be explored.

The variables arrest to first shock time, bystander CPR, Gender and age are significant at the initial stage (table 18). The first variable entered into the stepwise model is age, followed by bystander CPR and arrest to first shock time (table 19).

Variable	Mean	Standard deviation
Number of Shocks	3.06 shocks	2.19 shocks
Age of patient	65.22 years	10.33 years
Arrest-first shock time	12.32 minutes	8.69 minutes
Response time	6.12 minutes	3.91 minutes

Variable	Category	Frequency	Design Variable
Gender	Male	175	1
	Female	83	0
Arrest Witnessed	Yes	233	1
	No	25	0
Bystander CPR	Yes	148	1
	No	110	0

Table 17 - Description of variables in discharged/not discharged regression model 1

Variable	P-value
Arrest to first shock	0.0659
Bystander CPR	0.0029
Number of Shocks	0.9566
Gender	0.0260
Arrest Witnessed	0.1310
Age	0.0002
Response	0.9084

Table 18 - P-values at initial stage of discharged/not discharged model 1

Variable	P-value
Arrest to first shock	0.0742
Bystander CPR	0.0060
Number of Shocks	0.9192
Gender	0.1433
Arrest Witnessed	0.2690
Age	0.0007
Response	0.8908

Table 19 - P-values at final stage of discharged/not discharged model 1

Term	Exp.(Coef.)	95% Confidence limits
Age	1.04	1.02 , 1.07
Arrest to shock	1.03	0.994 , 1.07
Bystander CPR	0.48	0.28 , 0.82

Table 20 - Table of coefficients for discharged/not discharged model 1

The resulting model is :-

$$\text{logit}(P(\text{died})) = -2.62 + 0.044\,age + 0.030\,ArSh - 0.73\,BysCPR$$

where $ArSh$ = Arrest to first Shock time and $BysCPR$ = Bystander CPR.

The parameter estimates and their 95% confidence limits are shown in table 20. These results are consistent with the univariate analysis, although the 95% confidence interval for arrest to first shock time includes 1. As previously discussed (5.2.1) chest pain cases were excluded from the multivariate analysis due to missing data.

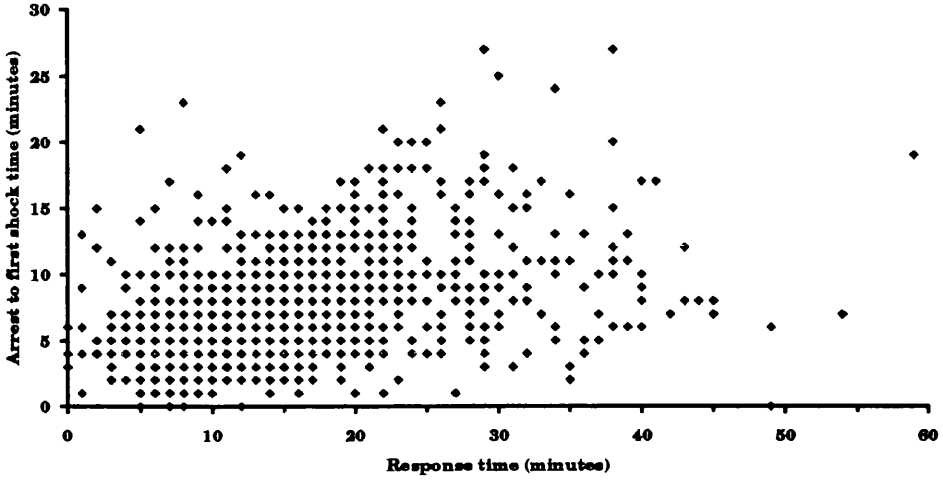

figure 15 - Correlation between response time and arrest to first shock time

Term	Exp.(Coef.)	95% Confidence limits
Gender	0.59	0.38 , 0.93
Age	1.03	1.01 , 1.05
Bystander CPR	0.47	0.31 , 0.71

Table 21 - Table of coefficients for discharged/not discharged model 2

The two variables response time and arrest to first shock time have a correlation coefficient of 0.375 (n=1366) (figure 15). There is therefore, perhaps a justification to re-run the model without the arrest to first shock time variable and hence increase the number of cases. The only problem is that the response time is confounded as a predictive variable for those cases where the patient arrests in between the vehicles despatch and the crew's arrival at the scene.

5.4.1.1 Model 2 - Discharged vs. Not Discharged

When the model is re-run with the exclusion of the arrest to first shock variable, the number of cases is increased to 402 (207 died ward, 195 discharged alive). The resulting model in this analysis is:-

$$\text{logit}(P(\text{died})) = -1.21 + 0.032\,age - 0.53\,gender - 0.75\,BysCPR$$

where *BysCPR*=bystander CPR

It is encouraging that the variables bystander CPR and age remain practically unchanged. Interestingly though, gender now enters the model (p=0.0194). Response time does not gain significance (p-value at final stage = 0.63). Odds ratios and 95% confidence intervals are presented in table 21. The odds of being discharged alive (having been admitted) are improved if the patient is male, of young age and received bystander CPR prior to admission. It would appear that the delay from arrest to first shock (or response time) is not such a significant factor in the ultimate survival of the patient once the patient has been admitted to a hospital ward.

5.4.1.2 Model 3 - Interactions in the Discharged/Not Discharged

To explore any interactions between variables the data used in model 2 were re-analysed. Interactions are more easily understood for categorical variables. For this reason, the variables response time, age and number of shocks have been transformed into binary variables. The median value for each variable has been used as a cut off point (table 22).

Variable	Category	Assigned value
Response time	<= 5 minutes	1
	> 5 minutes	0
Age	<=65 years	1
	>65 years	0
Number of shocks	<= 2 shocks	1
	>2 shocks	0

Table 22 - Re-coding of continuous variables to binary variables

Fitting the main effects only as in section 5.4.1.1., but with categorical variables re-coded as binary variables yields the same factors as significant i.e. gender, age and bystander CPR. The new model (3a) is :-

$$\text{logit}(P(\text{died})) = 1.024 - 0.37\,age - 0.53\,gender - 0.75\,BysCPR$$

where *BysCPR*=bystander CPR

One interaction term that would instinctively provide more useful information is that between bystander CPR and whether or not the arrest was witnessed. In an unwitnessed arrest there is some doubt as to the value of CPR (due to the obvious delay). Other possible interactions are (table 23) :

- age and bystander CPR.
- gender and bystander CPR.
- age and gender .
- response time and number of shocks.

Variable	Inter-action	Category	Frequency	Design Variable
Gender*Bys. CPR	1	Male & CPR	160	1
		Other	242	0
Arrest witnes.*Bys. CPR	2	Witnessed&CPR	202	1
		Other	200	0
Age*gender	3	<=65yrs & Male	142	1
		Other	260	0
Age*Bys. CPR	4	<=65yrs & CPR	112	1
		other	290	0
Response*number shocks	5	<=5mins &<=2shocks	103	1
		other	299	0

Table 23 - Description of interactions in discharged/not discharged model 3

Term	Exp.(Coef.)	95% Confidence limits
Arrest witnessed * Bys CPR	0.453	0.303 , 0.679
Age * sex	0.578	0.379 , 0.882

Table 24 - Table of coefficients for interaction model

All five interactions were entered in to the stepwise model. The result was that none of the main effects now entered the model. The interactions 1-4 were all significant (all $p<0.001$) at the first stage in the stepwise process. Interaction term 2 entered the model, followed by interaction 3. The coefficients & 95% confidence intervals are displayed in table 24. None of the main effects entered the model. The resulting model (3b) is :-

$$\text{logit}(P(\text{died})) = 0.65 - 0.79 bysCPR * arrwit - 0.55 age * gender$$

where *bysCPR*=bystander CPR, *arrwit*=arrest witnessed

Although the interactions appear more significant than the main effects , the improvement in the log-likelihood is minimal. Once again the most significant factor in the survival of the patient would appear to be bystander CPR (coupled with a witnessed arrest). If the main effects from model 3a (age, gender & Bystander CPR) are forced into the interaction model, neither of the interaction terms is now significant.

The resulting model conditioned on fitting the main effects first, would remain as before with no evidence of interaction. The interaction terms, significant in model 3b above are therefore surrogates for the main effects in the model 3a, and they therefore provide little additional information.

5.5 Predicting Hospital Discharge for Patients in VF when Crew Arrive

Analyses have been carried out for each stage of the resuscitation process. It is also of interest to see what factors at the outset of the resuscitation attempt influence ultimate survival to hospital discharge. There is no doubt that a shockable rhythm is the most essential component for a successful resuscitation. A stepwise logistic regression analysis was carried out for 2298 patients (195 survivors to hospital discharge), in a shockable rhythm on the arrival of the ambulance crew. Factors entered into the model were gender,

arrest witnessed (Y/N), age, ambulance response time, bystander CPR (Y/N) and number of shocks. Response time should be thought of as an approximation for arrest to first shock time (left out due to missing data).

Because of the small proportion of successes and the large number of factor combinations, computation time was slow and convergence of estimates was not always reached using the maximum likelihood (MLR) approach. This was also a problem in some of the other models, although not to the same extent. The resulting model was :-

$$\text{logit}(P(\text{died})) = 2.56 - 0.70\,arrwit + 0.066\,response - 0.83\,BysCPR + 0.12\,numshck$$

where *arrwit*=arrest witnessed, *BysCPR*=bystander CPR, *numshck*=number of shocks

Parameter estimates and their 95% confidence limits are displayed in table 25. They appear in the order they entered the model. Age and gender fail to enter this particular model. As expected presence of bystander CPR , a low number of shocks, a short response time and a witnessed arrest all improve the patients odds of surviving to hospital discharge. The receiver operating characteristic (ROC) curve (figure 16) demonstrates how poor the predictive power of the model is in defining a cut point for classification of patient outcome. The ideal would be to maximise specificity :-

$$\frac{\#\text{ patients discharged}}{\#\text{ correctly predicted as discharged} + \#\text{ incorrectly predicted as discharged}}$$

while maintaining a reasonable sensitivity. In this model a sensitivity of 67% yields a specificity of 59%, and a sensitivity of 52% yields a specificity of 72%.

Term	Exp.(Coef.)	95% Confidence limits
Bystander CPR	0.437	0.318, 0.598
Number of Shocks	1.13	1.06, 1.20
Response time	1.07	1.02, 1.11
Arrest Witnessed	0.498	0.315, 0.785

Table 25 - Table of coefficients for discharged/not discharged model 3

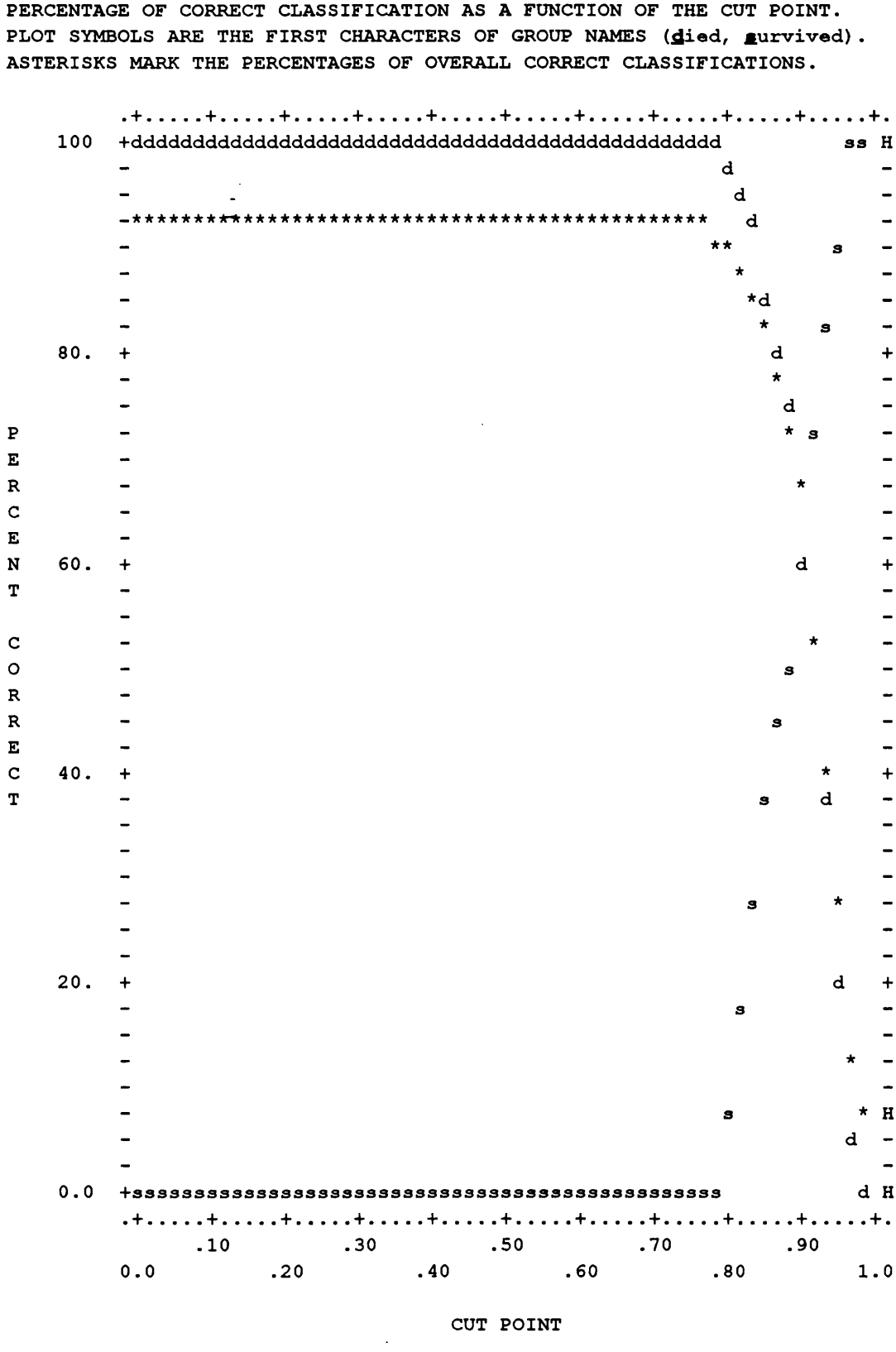

figure 16 - ROC curve for died/discharged model 3

5.6 Summary of Logistic Regression Analysis

We have identified three distinct stages in the cardiac arrest system.

- Presence of a shockable rhythm
- Admission to a hospital ward
- Discharge alive from hospital

The pre-hospital factors affecting survival at each stage were input into stepwise logistic regression models. Unfortunately we had no in-hospital data, such as time in intensive care and ventilation support (Y/N). Such factors may have been of interest at the final in-hospital stage. Significant factors at each stage are listed in figure 17. Factors whose 95% confidence interval included 1 or came within 1% of 1 have been excluded from the table.

In summary, male gender improves the patients odds of being shocked, but reduces the patients odds of ward admission once shocked. Given that the patient was admitted to a ward male gender once again improves the odds of being discharged alive. Bystander CPR is significant at each stage of the analysis. This is probably for three reasons :-

- It prolongs the patients cardiac rhythm and improves the chances of the patient being in a shockable rhythm on the arrival of the ambulance crew.
- It reduces the probability of hypoxic brain damage which is one of the main reasons for ceasing resuscitation in accident and emergency
- Hypoxic brain damage is also one of the main causes of death following hospital admission.

Other significant factors contributing to the patients admission to hospital are a low number of shocks (figure 18) and a short arrest to first shock time (figure 19, correlated with response time).

Analysis of interactions provided no extra predictive information when a sensible hierarchical approach to fitting the model was adopted. (i.e forcing the main effects into the model before fitting interaction terms).

Shockable Rhythm	**Ward Admission**	**Hospital Discharge (response time model)**
Male	Female	Male
Arrest Witnessed	-	-
-	-	Young age
Short response time	-	-
Bystander CPR	Bystander CPR	Bystander CPR
N/A	Low number of shocks	-
N/A	Low arrest to shock time	-

figure 17 - Factors for prediction of advancement through three stages of system

Looking at the overall model (Section 5.5) for all shocked patients we see that age and gender are not associated with outcome. The absence of gender can probably be explained by the phenomenon described above. i.e. although gender is significant in determining ward admission (female) and discharge from hospital (male) the overall proportion of each gender being discharged subsequent to being shocked is equivalent. Factors influencing hospital discharge at this early stage are bystander CPR, witnessed arrest, response time (arrest to first shock time was not used due to lack of data) and number of shocks.

Now that we have identified the factors leading to a successful resuscitation the next stage is to look at the patients' long term survival and the factors that contribute to it.

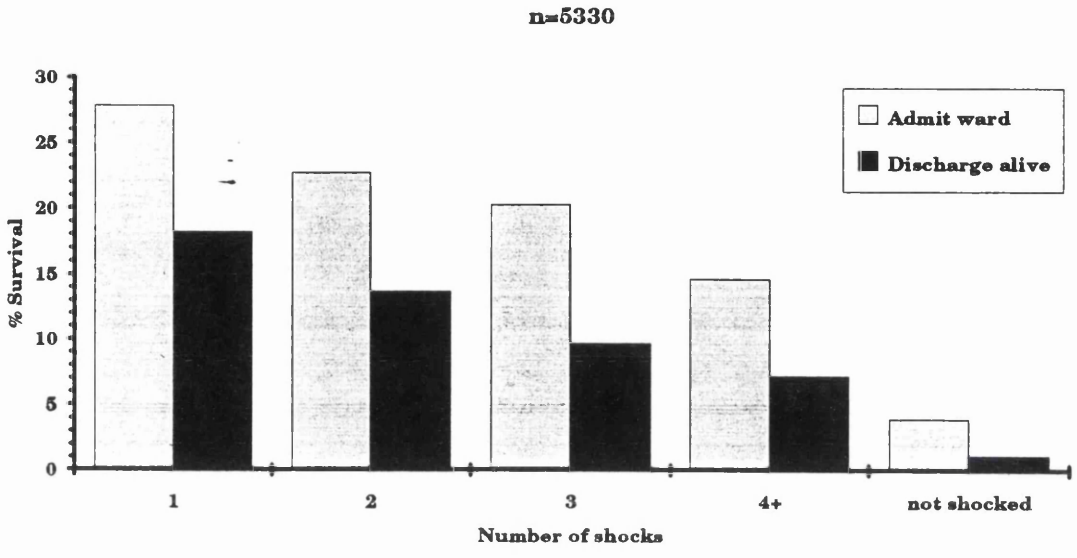

figure 18 - Number of shocks vs. survival

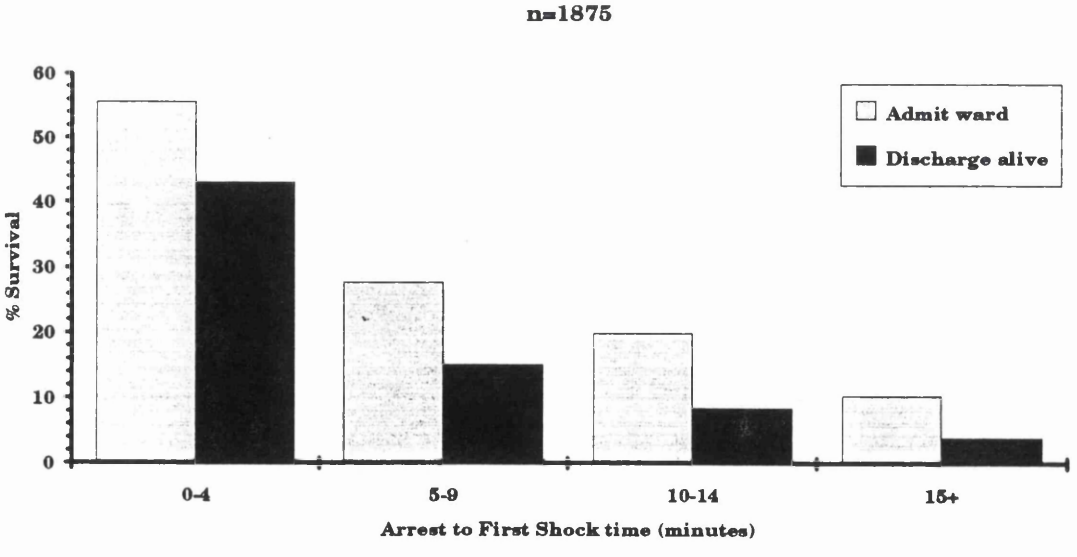

Figure 19 - Arrest to first shock time (mins) vs. survival

CHAPTER 6

Long-Term Survival from Out-of-Hospital Cardiac Arrest

6.1 Introduction

One of the main aims at the outset of the study was to determine the long term survival and quality of life of patients following initially successful resuscitation from out-of-hospital cardiac arrest (i.e. the sub-group of patients admitted to a hospital ward).

Dickey et al[24] looked into mortality within hospital following initially successful resuscitation. They found the major influencing factors (in a multivariate analysis) to be cardiogenic shock following defibrillation, coma on admission to hospital, age (>=60 years) and four or more shocks required to correct VF. Unfortunately we do not have complete data for this analysis. Our data collection concentrated on out-of-hospital data and survivor data. It was not feasible for us to access the medical records of those patients dying in hospital. We did look at the degree of in-hospital mortality but the emphasis here will be on survival following discharge.

A sample of 924 patients, 458 survivors and 466 non-survivors were selected for analysis from approximately 7000 cardiac arrests occurring between October 1988 and July 1993. The basis for patient selection was full outcome information available.. Data on age, gender and length of stay of the patients were analysed. Survival ranged from a few hours to 368 days in the subgroup of 466 patients dying in hospital . Hospital stay in the 458 patients discharged alive ranged from 1 day (a gentleman who discharged himself) to 277 days. A breakdown of age, stay and gender is illustrated in table 26.

	Died Hospital	**Discharged Alive**
Median Age (IQR)	68 years (59-74 years)	63 years (55-70 years)
Median Stay (IQR)	1 day (1-5 days)	10 days (8-14 days)
Male:Female Ratio	1.5:1	3.1:1

Table 26 - Median age, stay and gender of patients admitted to a hospital ward

Those patients going to die in hospital, do so early (<5 days) and don't use up hospital resources for long time periods prior to subsequent death. Unfortunately we do not have sufficient clinical details on these patients, or accurate cause of death data to do any more detailed in hospital analyses. The logistic regression in Section 5.4 identified the pre-hospital arrest details distinguishing those patients dying in hospital to those being discharged alive.

6.2 Data Collection on 458 Survivors

For all patients discharged alive from hospital, discharge summaries were reviewed to determine the underlying cause of the cardiac arrest, and the patients prescribed drugs and subsequent therapy and investigations e.g. Automatic Implantable Cardiac Defibrillator (AICD), Coronary angiography, Electrophysiological study. If the discharge summary failed to provide all the necessary information the patient's case notes were requested from the patient's General Practitioner or Hospital Consultant. Two clinical details forms were completed for each patient (appendix 7) which included Electrocardiogram (ECG) and cardiac enzyme information in addition to management and treatment information. Once completed, the data for each patient were entered onto the Paradox database. Professor Cobbe is aware that categorising patients by arrest type can be a subjective process and the diagnosis of arrest type was therefore based on a strict set of criteria (figure **). The breakdown of cause of arrest with age is shown in table 27. The Myocardial Infarction patients are significantly younger than the Ischaemia patients (p=0.0001) and the Primary VF patients (p=0.0007).

Myocardial Infarction (MI)	Chest Pain ,Sequential ECG changes, (New Q-Waves or ST elevation)
Ischaemia / Non Q Wave MI	Chest Pain, ST Depression and/or T wave inversion, No New Q Wave development
Primary VF	Previous MI or CHF, Instantaneous Collapse without pain, No sequential ECG changes.

Figure 20-Criteria for cause of cardiac arrest in survivors

Cause	Number of Patients (%)	Age in years (Median,(IQR))
Myocardial infarction (Q-Wave & Unspecified)	242 (53%)	61 years (53.75-68 years)
Ischaemia (+ Non Q-Wave MIs)	96 (21%)	66.5 years (59.25-72 years)
Primary ventricular fibrillation	87 (19%)	67 years (58-71 years)
Other	24 (5%)	54.5 years (34.5-70 years)
Inadequate information	9 (2%)	71 years (59.5-79.5 years)

Table 27 - Cause of arrest (with age) in survivors

Arrest due to other causes included electric shock, apnoeic attacks (baby), severe asthma attack, drug overdose and cerebral ischaemia. Outcome following hospital discharge was favourable, with 409 (89%) of the 458 patients being regarded as conscious and normal . Of the others, one was in a coma and subsequently discharged to long term care, 36 (8%) suffered moderate neurological disability, 8 (2%) severe disability and 4 (1%) neurological outcomes were unknown. It should be noted that details of neurological status before the event were unknown and therefore some of the patients' disabilities may not have been due to the cardiac arrest. Destination on discharge was to their own home or a relative's home in 432 (94%) cases. 13 patients were transferred to an acute hospital, 7 to a long stay facility and 6 to a rehabilitation unit (e.g. Astley Ainslie Hospital, Edinburgh).

Patient Mortality was observed over the study period by means of 'flagging' patients with the Registrar General for Scotland. All 458 patients have been 'flagged'. Lifetimes are calculated from the date of cardiac arrest until date of death or 1st June, 1993 whichever occurred first. The mean survival (follow-up) time was 1305 days (77% of observations censored). During the study period there were 105 deaths (median 221 days, range 0-1368 days). The split of the ages of survivors vs. non survivors for the whole group and by arrest type is shown in table 28. The causes of death in the 105 patients that died are listed in table 29. Deaths due to Ischaemic Heart Disease (ICD codes 410-414) constituted 76% of all deaths.

Arrest type	Died during study period n, Median age (IQR)	Survived to 1st June, 1993 n, Median age (IQR)
Whole Group	n=105 67 years (59-71 years)	n=353 62 years (54-69 years)
Myocardial Infarction	n=40 60 years (52.25-67 years)	n=197 63.5 years (56.75-69 yrs)
Ischaemia (+Non Q Wave MI)	n=24 64 years(57.75-71 years)	n=69 69 years(66-77.5 years)
Primary Ventricular Fibrillation	n=28 66 years(56-70.25 years)	n=57 67 years(60-73.5 years)

Table 28 - Ages of survivors vs. non survivors

Cause of Death (ICD Codes)	Total
Ischaemic Heart Disease (410-414)	80
Other Forms of Heart Disease (420-429)	4
Malignant Neoplasm of Digestive Organs & Peritoneum (150-159)	4
Cerebrovascular disease (430-438)	7
Diseases of the Respiratory System (460-519)	3
Malignant Neoplasm of Respiratory & Intrathoracic Organs (160-165)	2
Malignant Neoplasm of Genitourinary Organs (179-189)	2
Mental Disorders - Other Psychoses (295-299)	1
Diseases of Arteries, Arterioles & Capillaries (440-448)	1
Diseases of Skin, Musculoskeletal System & Connective Tissue (680-739)	1

Table 29 - Causes of death in survivors

Of the 105 patients who died following hospital discharge, 49 patients were declared dead out-of-hospital and 56 in hospital. The out-of-hospital deaths can be regarded as "sudden deaths" and these are of most interest. Unfortunately, many of the apparent in hospital deaths will also have been sudden i.e. patient died outside hospital but was not declared dead until arrival in hospital casualty department. Following analysis of the Heartstart Paradox database it was discovered that 10 of the patients registered as dying in hospital

had in fact suffered recurrent cardiac arrests prior to admission. 5 were declared dead on arrival and 5 died following hospital admission . These 10 deaths will be regarded as 'sudden' for analysis purposes. Only deaths due to Ischaemic Heart Disease (ICD codes 410-414) and other forms of heart disease (420-429) were considered for the sudden death analysis. The break down of cause of eventual death by cause of initial arrest is shown in table 30. It is of interest to identify the group at highest risk of recurrent sudden cardiac death. This group is the primary VF group, where 18/29 (62%) deaths were sudden cardiac deaths. It may be necessary to look at ways of improving post discharge care in this group.

Cause of First arrest	**Subsequent Cause of Death**		
	Sudden Cardiac	**Non-Sudden Cardiac**	**Other**
Myocardial Infarction	22	11	9
Ischaemia (+Non Q Wave MI)	9	10	7
Primary VF	18	8	3
Other Cause	2	1	2
Inadequate Information	3	0	0
Total	54	30	21
Median age	67 years	69 years	66 years
(IQR)	57.75-71 years	65.5-72.5 years	57.5-71 years

Table 30: Cause of initial cardiac arrest vs. cause of death

6.3 Survival Analysis

The survivor function is the probability that a patient will survive to at least a specified time. Survival data are analysed using the product-limit (PL) estimate of the survivor function; sometimes known as the Kaplan-Meier estimate[25]. This provides a non-parametric estimate of the survivor function for the life distribution under study. In this case, this consists of lifetimes of 458 resuscitated cardiac arrest patients following discharge from hospital.

6.3.1 The Product-Limit (PL) Estimate

Definition

The PL estimate is defined as follows[26];

Suppose there are observations on n individuals and that there are k ($k<=n$) distinct times $t_1<t_2<.....<t_k$ at which deaths occur. The possibility of there being more than one death at t_j is allowed, and we let d_j represent the number of deaths at t_j. In addition to the lifetimes $t_1,....,t_k$, there are also censoring times L_i for individuals whose lifetimes are not observed. The PL estimate of $S(t)$ is defined as:-

$$\hat{S}(t) = \prod_{j:t_j<t} \frac{n_j - d_j}{n_j}$$

where n_j is the number of individuals at risk at time t_j, that is the number of individuals alive and uncensored immediately prior to tj.

The Mantel Cox (log-rank) test statistic

The Mantel Cox test is a non-parametric linear-rank test[27] that gives equal weight to all observations. This is the test that is used to test for equality of survival curves in our analyses.

6.3.2 Product Limit Estimates of Survival

Product limit estimates were employed to explore survival trends in the 458 survivors. Patients were stratified by factors such as age group, gender, cause of arrest and previous cardiac history. The BMDP program 1L "Life tables and survivor functions" was used for

the analysis. Data from the BMDP output were exported into Microsoft Excel to generate the survival graphs. All results are presented as annual product limit estimates with numbers at risk in brackets.

6.3.2.1 All Cause, Cardiac and 'Sudden Death' Mortality

In order to ease interpretation of the survival curve plots, the number of patients at risk over 6 month intervals is tabulated in table 31 . All 105 deaths are included and there are no patients lost to follow up. 77% of the observations were censored.

Days	Months	Number of patients who remain at risk
0 days	0 Months	458
182.5days	6 Months	413
365 days	1 Year	356
547.5 days	1 Year 6 months	273
730 days	2 Years	201
912.5 days	2 Years 6 months	138
1095 days	3 years	61
1277.5 days	3 Years 6 months	47
1460 days	4 years	17

Table 31 - Number of patients in whole population at risk, deaths due to all causes

The PL estimates for all cause mortality are shown in table 32. 66.7% (70) of all deaths occurred within the first year following hospital discharge and 15% of all deaths occurred within the first month (figure 21).

Censoring deaths due to other causes table 33 shows the product limit estimates of survival based on the 84 deaths due to heart disease (ICD Codes 410-414 and 420-429). From a cardiologists view point, these are the post-discharge deaths of most interest. Obviously patient deaths, ICD coded as due to cancers and other diseases can not necessarily be attributed to the initial cardiac arrest event.

Censoring all deaths apart from the 54 sudden cardiac deaths, PL estimates for survival are shown in table 34. Figure 22 shows all cause deaths, cardiac deaths and sudden cardiac deaths over the whole period. Other factors influencing mortality have to be considered, such as age, gender, underlying cause of arrest and previous heart disease.

1 year	85% (356)
2 year	77% (201)
3 year	74% (61)
4 year	70% (17)

Table 32 - PL estimates for 105 deaths due to all causes

1 year	87% (357)
2 year	81% (202)
3 year	78% (62)
4 year	76% (18)

Table 33 - PL estimates for 84 deaths due to heart disease

1 year	92% (357)
2 year	87% (202)
3 year	85% (62)
4 year	85% (18)

Table 34 - PL estimates for 54 'sudden deaths'

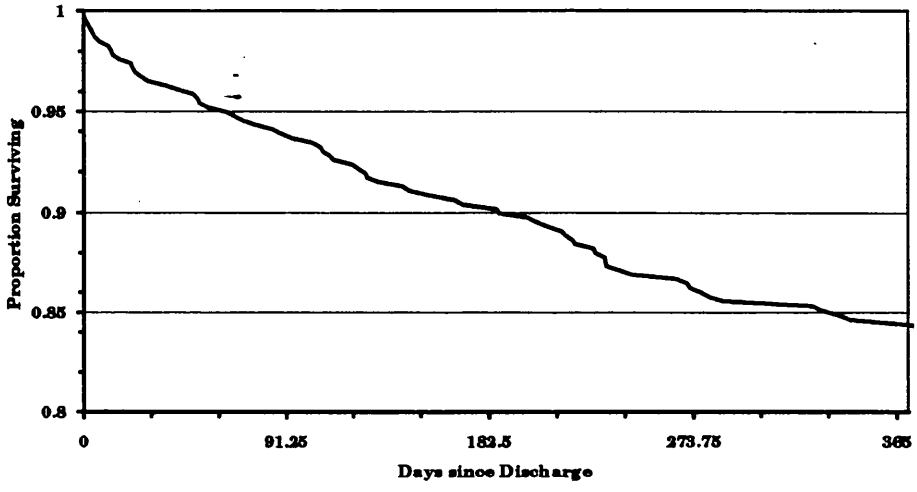

Figure 21 - Survival curve of 1 year survival, death from all causes

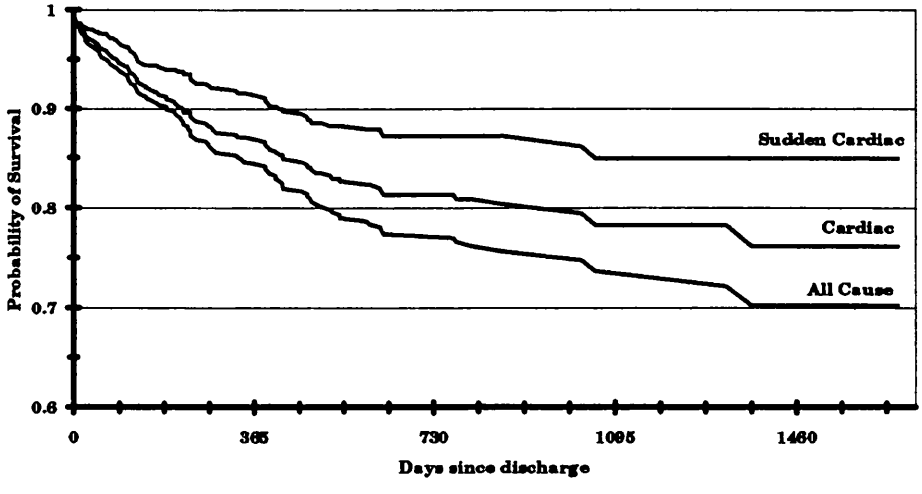

Figure 22- Survival curves for all cause, cardiac and sudden cardiac mortality

6.3.2.2 Gender and Age

Survival curves for males and females implied no difference (table 35). This hypothesis was backed up by the test statistic for equality of survival curves. It should be noted that the female group were approximately 3 years older than the males .

	Males (n=346)	Females (n=112)
1 year	85% (267)	84% (90)
2 year	78% (154)	76% (48)
3 year	73% (46)	76% (16)

Table 35 - PL estimates for males and females

The median age for the base population was 65 years. Initially PL estimates for patients age <=65 years vs. estimates for patients >65 years were considered (table 36). Mantel-Cox significance level for equality of survivor functions, p=0.0004. Because of the magnitude of the difference in survival, it was decided that age quartiles might be more appropriate as 4 groups would provide more information about the effect of age on mortality than two. There is great interest in resuscitation of "old" people (70+ years), and whether it is a worthwhile intervention, when associated with morbidity and mortality following successful resuscitation and hospital discharge.

Time since Discharge	PL estimate (<= 65 years)	PL estimate (> 65 years)
1 year	89%	79%
2 years	83%	71%
3 years	81%	65%

Table 36 - PL estimates for <=65 years vs. >65 years

Time since Discharge	PL estimate (< 55 years) n=108	PL estimate (55-64 years) n=137	PL estimate (65-69 years) n=96	PL estimate (70+ years) n=117
1 year	93% (89)	87% (110)	77% (72)	81% (86)
2 years	90% (59)	77% (52)	72% (48)	71% (43)
3 years	87% (21)	77% (14)	66% (14)	66% (11)

Table 37 - PL estimates of four age groups

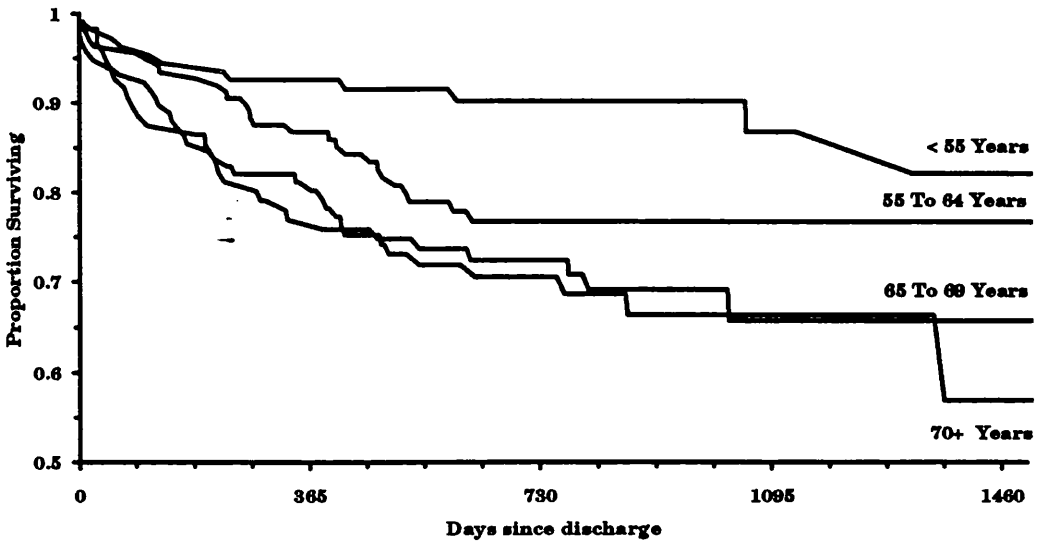

Figure 23 - Survival curves for four age groups (all cause)

Testing for equality of survivor functions once the data is split into four gives p=0.0021 (table 37 & figure 23). It is interesting that 1 year mortality is higher in the 65-69 years group than in the 70+years group. Table 23 shows the result of pairwise comparisons unadjusted for multiple comparisons.

Comparison	p-value
<55 vs. 55-64 years	0.029
<55 vs. 65-69 years	0.001
<55 vs. 70+ years	<0.001
55-64 vs. 65-69 years	0.160
55-64 vs. 70+ years	0.095
65-69 years vs. 70+ years	0.833

Table 38 - P-values for equality of survival curves for 4 age groups

6.3.2.3 Arrest Type

Figure 24 illustrates the survival curves for the three defined arrest types due to a cardiac cause : myocardial infarction, ischaemia and primary ventricular fibrillation. PL estimates of survival are shown in table 39. Testing for equality of survivor functions p=0.0099. Table 40 shows the results of pairwise comparisons unadjusted for multiple comparisons.

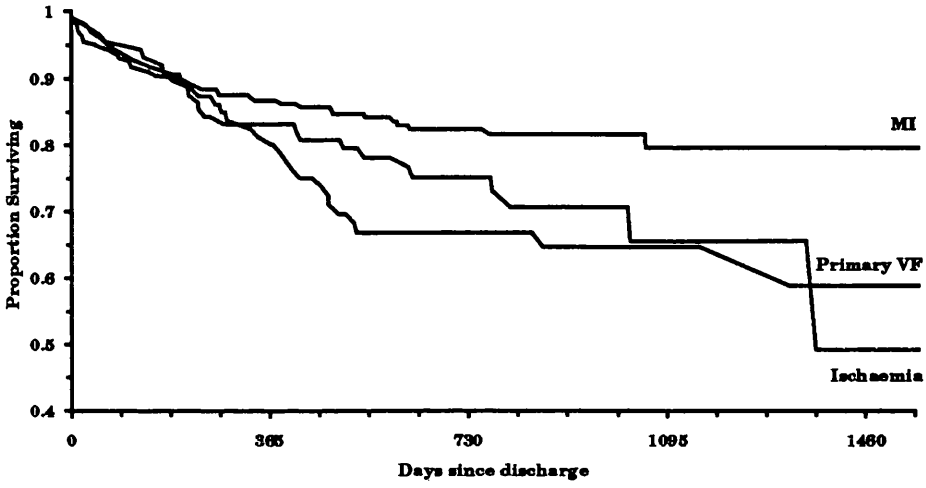

Figure 24 - Survival curves for three arrest types

	MI (n=242)	Isch. (n=96)	VF (n=87)
1 year	87% (191)	83% (73)	81% (66)
2 year	82% (116)	75% (37)	67% (35)
3 year	80% (37)	66% (10)	65% (14)

Table 39 - PL estimates of survival by arrest type

Comparison	p-value
MI vs. Ischaemia	0.049
MI vs. VF	0.004
Ischaemia vs. VF	0.484

Table 40 - P-values for equality of survival curves for 3 arrest types

6.3.2.4 Previous Myocardial Infarction

It would be expected that a patient who had suffered a myocardial infarction at some time prior to his/her cardiac arrest would have a poorer prognosis than the patient with no previous history. This is indeed the case (table 41). Testing for equality of survival curves yields p=0.0064. Patients where past history was unknown have been excluded from the analysis.

	Previous MI (n=134)	No Previous MI (n=201)
1 year	83% (105)	87%(157)
2 year	72% (53)	83% (93)
3 year	66% (16)	81% (30)

Table 41 - PL estimates for previous MI

6.4 Post-Discharge Management

Two clinical details forms were completed for all 458 survivors. Obviously drugs or treatments not specified on the discharge summaries are not included in our analysis. Management was unknown in 15 patients, leaving 443 for analysis (table 42).

Treatment	whole group (n=443)	MI (n=237)	Ischaemia (n=93)	VF (n=85)
Thrombolytic therapy (on admission)	28%	47%	13%	2%
No therapy	3%	1%	5%	2%
Beta-Blocker	27%	31%	34%	15%
Other Anti Ischaemic	28%	30%	32%	25%
Refer for Coronary angiography	13%	9%	20%	18%
Refer for EPS	4%	1%	8%	12%
Aspirin	68%	81%	60%	55%
Anti coagulants	7%	6%	4%	9%
Diuretics	32%	30%	26%	47%
Exercise test	18%	23%	22%	5%
ACE Inhibitor	16%	16%	8%	32%
Anti-Arrhythmic	22%	12%	22%	53%
Other	19%	14%	20%	29%

Table 42 - % of patients receiving treatment in various diagnostic groups

6.4.1 Drugs in the Treatment of Cardiac Arrest Survivors

Five main drug categories are analysed in the product limit and Cox-proportional hazards analyses to follow. These are aspirin, thrombolytic therapy, beta-blockers, diuretics/ACE Inhibitors and anti-arrhythmics and are prescribed dependent on underlying cause of initial arrest and any contra-indications that may be present.

6.4.1.1 Aspirin

68% of all the cardiac arrest survivors and 81% of surviving patients whose arrest was due to an MI were put on aspirin when discharged from hospital. Aspirin is an anti platelet drug[28]. By decreasing platelet aggregation it inhibits the formation of coronary thrombus. Aspirin is commonly used for secondary prevention of cardiovascular disease and has been shown to lower post-MI mortality by up to 23% (Second International Study of Infarct Survival (ISIS-2)[29]). It is contra-indicated by active peptic ulceration and bleeding disorders such as haemophilia.

6.4.1.2 Thrombolytic Therapy

Most cases of acute MI are due to the sudden obstruction of a coronary artery by the formation of a thrombus. Thrombolytic agents are known as 'clot-busters' as they cause a chemical reaction resulting in the dissolving of the thrombus (or clot). One thrombolytic agent, streptokinase has been shown to improve early post- MI mortality by 25% (ISIS-2). The ISIS-2 trial also showed that early mortality was lowered by 42% if both streptokinase and aspirin were administered to the patient. In addition to improved survival, the early administration of thrombolytic agents often leads to better recovery of left ventricular function. 28% of all patients in our study were given thrombolytic therapy post-arrest (47% in the MI group). Approximately 20% of arteries fail to open with the provision of these agents and much of the benefit of successful thrombolysis can be lost if re-oclussion of the infarct related artery occurs. The most important risk from these drugs is bleeding, but various studies have shown this risk to be negligible (0.3-0.6%)[30].

6.4.1.3 Beta Blockers

27% of all patients were prescribed beta-blockers on discharge. The rapid beating of the heart is caused by stimulation through nerve endings called beta-receptors. These drugs act by blocking the beta-receptors. They slow the heart and may precipitate heart failure in patients who are near such a state. Several studies have shown that some beta-blockers can cause a reduction in the recurrence rate of MI. However, pre-existing heart failure, hypotension, brady-arrhythmias and obstructive airways disease render beta-blockers unsuitable in some patients post-MI. It is not known whether the protective effect of these drugs continues after 2 years. It is possible that sudden cessation can cause a rebound worsening of myocardial ischaemia.

6.4.1.4 Diuretic/ ACE Inhibitors

These two drugs tend to be an indicator for heart failure if prescribed to the cardiac arrest patients on discharge from hospital. In studies of the major chronic illnesses such as diabetes, arthritis and hypertension, heart failure had the greatest negative impact on quality of life[31]. In some cases annual mortality may exceed 60%. Quite often diuretics are used in combination with an angiotensive converting enzyme (ACE) Inhibitor. Patients with heart failure should be considered for ACE Inhibitor treatment even if they have been rendered asymptomatic by a diuretic. In our group, 23% (100) were on diuretics only, 7% (32) were on ACE Inhibitors only and 9% (41) were on both.

6.4.1.5 Anti-Arrhythmic

A cardiac arrhythmia is an abnormality of cardiac rhythm of any type. Normal sinus rhythm is arbitrarily defined as a rate between 60 and 100 per minute. Arrhythmias may be present in the absence of cardiac disease, but are more commonly linked with structural heart disease or external provocative factors. Anti-arrhythmic drugs are prescribed when there is a high risk of recurrent ventricular tachycardia or sudden death. As we saw in section 6.2 , 62% of deaths of patients whose initial arrest was due to a primary VF event were sudden cardiac deaths. Unless there is a clear precipitating factor such as drug toxicity, electrolyte abnormality or acute ischaemia, patients with documented ventricular tachycardia require anti-arrhythmic drugs (personal communication Professor Cobbe). 53% of primary VF patients and 22% of all patients were prescribed an anti-arrhythmic drug on discharge

6.4.2 Product limit Estimates of Survival

Treatment details were available on 443 patients. Product limit estimates were calculated for presence/absence of Aspirin, Beta-blockers, Thrombolytic therapy, Anti-arrhythmic therapy and Diuretic and/or ACE inhibitor as stated on patient discharge letters. Table 43 shows product limit estimates of survival at 1 year, 2 years and 3 years for aspirin, beta-blockers, diuretics/ACE Inhibitors, anti-arrhythmics and thrombolytic therapy. Mantel-Cox significance levels for equality of survivor functions are shown below each individual table.

	Aspirin (n=302)	No Aspirin (n=141)
1 year	88% (247)	80% (102)
2 year	82% (141)	70% (54)
3 year	77% (43)	69% (17)

p=0.0021

	Beta-blocker (n=121)	No Beta-blocker (n=322)
1 year	92% (104)	83% (245)
2 year	88.5% (64)	74% (131)
3 year	79% (20)	73% (40)

p=0.0068

	Diuretic and/or ACE Inhibitor (n=173)	No Diuretic or ACE Inhibitor (n=270)
1 year	81% (126)	89% (223)
2 year	67% (55)	85% (140)
3 year	61% (15)	82% (45)

p<0.0001

	Anti-arrhythmic (n=99)	No Anti-arrhythmic (n=344)
1 year	81% (75)	87% (274)
2 year	67% (38)	81% (157)
3 year	67% (16)	76% (44)

p=0.0267

	Thrombolytic Therapy (n=126)	No Thrombolytic Therapy (n=317)
1 year	90% (99)	84% (250)
2 year	87% (64)	75% (131)
3 year	82% (17)	71% (43)

p=0.0099

Table 43 - PL estimates for drug therapy in survivors

All the analyses show a significant difference between the survival functions. In the case of aspirin, beta-blockade and thrombolysis presence of the drugs is associated with a

beneficial effect. In the case of diuretic and/or ace inhibitor and anti-arrhythmic therapy presence of the drugs is associated with a negative effect on survival. If we breakdown each group in relation to median age it is apparent that age may be confounding the drug effect (table 44). This analysis suggests that older patients are treated more conservatively than their younger counterparts. Aspirin, Beta blockers and Thrombolysis are prescribed to a younger group of patients, while anti-arrhythmics and diuretics/ACE inhibitors are prescribed to older patients. Evidence of heart failure is also a key confounding factor as will be discussed later in this chapter.

Drug management can depend on the underlying cause of the cardiac arrest. It is therefore interesting to examine drug effects within each arrest type grouping, as some drug effects are not significant within certain arrest types (NB it is difficult to tell whether this is due to reduced sample sizes). If the percentage of patients on a drug was less than 25% or greater than 75% the drug effect was not tested. The exception is aspirin within the MI group as this analysis is of clinical significance. 81% of MI patients were on aspirin.

	Drug	No Drug	p
Aspirin	62 yrs (54-69 yrs)	66 yrs (56.5-73 yrs)	0.0035
Beta-blocker	59 yrs (51-66 yrs)	66 yrs (57-70.25 yrs)	<0.0001
Diuretic/ACE Inhib.	67 yrs (58-71 yrs)	62 yrs (52-68.25 yrs)	<0.0001
Anti-arrhythmic	66 yrs (57-69 yrs)	62.5 yrs (54.25-69 yrs)	0.1874
Thrombolysis	60 yrs (52-67 yrs)	65 yrs (56.5-70yrs)	0.0002

Table 44 - Median patient age (IQR) vs. drug therapy

6.4.2.1 Myocardial Infarction

In this group of patients those taking aspirin or beta-blockers appeared to be associated with a reduced risk of recurrent death, whereas those taking diuretic/ACE Inhibitors were associated with an increased risk. Although the product-limit estimates for the thrombolytic group appear different , the results were not significant. This may be due to the small sample size (table 45).

	Aspirin (n=192)	No Aspirin (n=45)
1 year	92% (162)	69% (26)
2 year	88% (96)	63% (17)
3 year	84% (28)	63% (8)

p<0.0001

	Beta-blocker (n=73)	No Beta-blocker (n=164)
1 year	94% (63)	84% (125)
2 year	93% (37)	78% (76)
3 year	86% (11)	77% (24)

p=0.0166

	Diuretic and/or ACE Inhibitor (n=95)	No Diuretic or ACE Inhibitor (n=142))
1 year	81% (68)	91% (120)
2 year	72% (30)	90% (83)
3 year	70% (8)	87% (27)

p=0.0007

	Thrombolytic Therapy (n=111)	No Thrombolytic Therapy (n=126)
1 year	90% (86)	85% (102)
2 year	87% (57)	79% (56)
3 year	86% (15)	76% (20)

NS (p=0.1263)

Table 45 - PL estimates for drug therapies in MI

6.4.2.2 Ischaemia

None of the drugs were significantly associated with an increased/decreased the risk of patient mortality in the ischaemia group (table 46).

	Aspirin (n=56)	No Aspirin (n=37)
1 year	86% (44)	83% (28)
2 year	78% (22)	74% (14)
3 year	66% (6)	68% (4)

NS (p=0.5866)

	Beta-blocker (n=32)	No Beta-blocker (n=61)
1 year	87.5% (27)	84% (45)
2 year	81% (18)	74% (19)
3 year	67% (6)	70% (4)

NS (p=0.5258)

	Diuretic and/or ACE Inhibitor (n=25)	No Diuretic or ACE Inhibitor (n=68)
1 year	92% (19)	82% (53)
2 year	81% (11)	75% (26)
3 year	55% (3)	72% (9)

NS (p=0.94)

Table 46 - PL estimates for drug therapies in Ischaemia

6.4.2.3 Primary VF

Presence of diuretics/ACE Inhibitors was associated with an increase in the patient's risk of recurrent death . In the group of 46 patients receiving no diuretic or ACE inhibitor all 20 (43.5%) of the patients that are deceased, died within 1 year 6 months following discharge (table 47).

	Aspirin (n=47)	No Aspirin (n=38)
1 year	81% (36)	84% (29)
2 year	68.5% (21)	65% (13)
3 year	65% (9)	65% (5)

NS (p=0.6883)

	Diuretic and/or ACE Inhibitor (n=46)	No Diuretic or ACE Inhibitor (n=39)
1 year	76% (34)	89% (31)
2 year	55% (13)	83% (21)
3 year	55% (3)	79% (10)

p=0.0203

	Anti-arrhythmic (n=45)	No Anti-arrhythmic (n=40)
1 year	84% (36)	80% (29)
2 year	67% (17)	68% (17)
3 year	67% (7)	63% (7)

NS (p=0.6831)

Table 47 - PL estimates for drug therapies in Primary VF

6.5 Cox Proportional Hazards Model

Models in which factors related to lifetime have a multiplicative effect on the hazard function play an important part in the analysis of lifetime data[26]. We have used a distribution free approach to data analysis based on proportional hazards models, first suggested by David Cox in 1972[32].

6.5.1 Definition

Let T be a continuous random variable representing an individuals lifetime, and let $\mathbf{x}=(x_1,...,x_p)$ be a known row vector of regressor variables associated with the individual. Under Cox's proportional hazards assumption the hazard function of T, given $\mathbf{x}$, is:-

$$h(t|\mathbf{x}) = h_0(t)\exp(\mathbf{x}\beta)$$

where $\beta=(\beta_1,....\beta_p)'$ is a vector of regression coefficients. The approach taken is a distribution free one and no specific form is assumed for $h_0(t)$. The model implicitly contains two assumptions:

1. The multiplicative relationship between the underlying hazard function and the log-linear function of the covariates (the proportionality assumption). The ratio of the hazard functions for two individuals with different sets of covariates does therefore not depend upon time.

2. The effect of covariates upon the hazard function is log-linear.

Estimations of the regression parameters are obtained in the following way. Suppose that a random sample of n individuals yields a sample with k distinct observed lifetimes and n-k censoring times. The k observed lifetimes will be denoted by

$$t_{(1)} <...< t_{(k)} \text{ ,and } R_i = R(t_{(i)})$$

will be used to represent the risk set at time t(i), that is, the set of individuals alive and uncensored just prior to t(i).

The conditional probability that an individual with covariate vector $\mathbf{x}_i$ responds at time t_i, given that a single response occurs at t_i, and given the risk set R_i, is the ratio of the hazards:-

$$\frac{\exp(\mathbf{x}_{(i)}\beta)}{\sum_{l \in R_i} \exp(\mathbf{x}_{(l)}\beta)}$$

Multiplying these probabilities together for each of the k distinct response times gives the partial likelihood function :-

$$L(\beta) = \prod_{i=1}^{k} \left(\frac{\exp(\mathbf{x}_{(i)}\beta)}{\sum_{l \in R_i} \exp(\mathbf{x}_{(l)}\beta)} \right)$$

6.5.2 Main Effects Model

A Cox proportional hazards stepwise analysis was performed to assess which factors have a dominating influence on survival. Variables included were age (as a continuous variable), duration of hospital stay, arrest type and drug therapy. Only the arrest types Myocardial Infarction, ischaemia (+ non-Q Wave MI) and primary ventricular fibrillation groups were included. The variable 'shocked' was not included due to the small number of non-shocked successful resuscitations. History of MI was also excluded due to the proportion of 'don't knows'.

The analysis was carried out using BMDP program 2L. Presence of a drug was coded as 1 and absence as 0. A hazard ratio of >1 can therefore be interpreted as a patient on the drug having an increased risk of death.

Initially arrest type was included as a continuous variable , based on the results of the Product-Limit analysis i.e. MI mortality (1) < Ischaemia Mortality (2) < Primary VF Mortality (3). This is somewhat simplistic approach, but a useful starting point. There is some doubt as to whether the proportional hazards assumption holds for the three arrest types, as we saw in the product limit analysis (6.3.2.3).

6.5.2.1 Model 1 -Arrest Type as a Continuous Variable

This stepwise model generated included age, diuretic and/or ACE inhibitor and arrest type. There were 415 cases for analysis (table 48). At stage 1, 7 variables fit the entry criteria ($p<0.1$) (table 48). Table 50 shows the order of entry. Once age was entered, anti-arrhythmic therapy dropped out, and 5 variables still satisfied the entry criteria.. Following the entry of diuretic/ACE therapy into the model, beta-blockers failed to meet the entry criteria and 3 variables remained. Once arrest type was entered aspirin ($p=0.1022$) and thrombolysis ($p=0.2349$) dropped out as potential entrants. The fitted model had the coefficient values and corresponding standard errors shown in table 51.

Total	Died	Survived	Percent Censored
415	92	323	0.7783

Table 48 - Total patients and % censored

Variable	P-Value
Gender	0.8268
Age	0.0001
Hospital Stay	0.7690
Beta-blocker	0.0064
Aspirin	0.0004
Diuretic/ACE	0.0001
Anti-arrhythmic	0.0914
Thrombolysis	0.0071
Arrest Type	0.0039

Table 49 - Initial table of p-values to enter

Step	Variable	P-Value
1	Age	0.0001
2	Diur /ACE	0.0019
3	Type	0.0282

Table 50 -p-values values to enter variables in the model

Variable	Coefficient	Standard Error	Hazard Ratio
Age	0.0316	0.0109	1.0321
Diur/ACE	0.6410	0.2158	1.8983
Type-	0.2718	0.1222	1.3123

Table 51 - Coefficients for Cox model 1

As before young age, absence of diuretic/ACE treatment and arrest due to Myocardial infarction are positive factors for long term survival. Diuretic/ACE treatment is an indicator for patients in heart failure, thus its negative effect on long-term survival. Figures 25 & 26 look at the case of a 65 year old patient on diuretics/ACE inhibitors vs. a 65 yr old patient not on either drug for each of the three arrest types. Even for a patient suffering an arrest due to an MI the prognosis is extremely poor if the patient is on diuretic or ACE therapy.

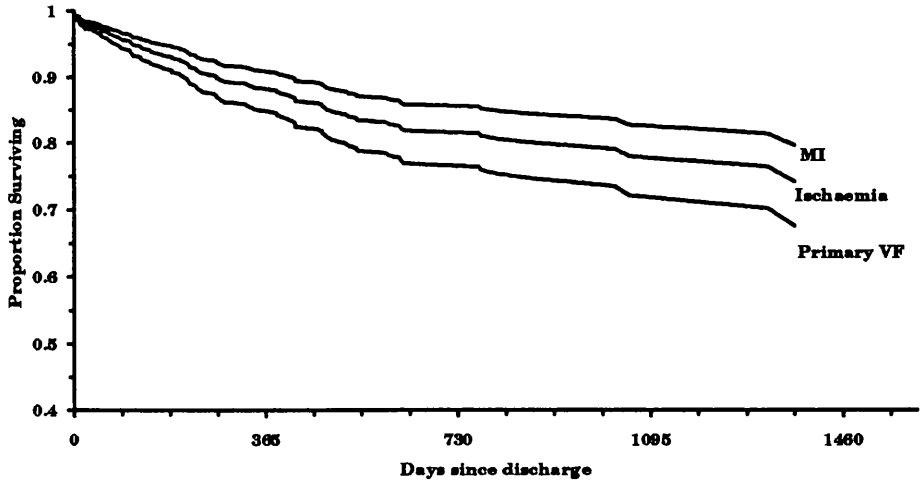

Figure 25 - 65 year old patient, not on diuretics or ACE Inhibitors

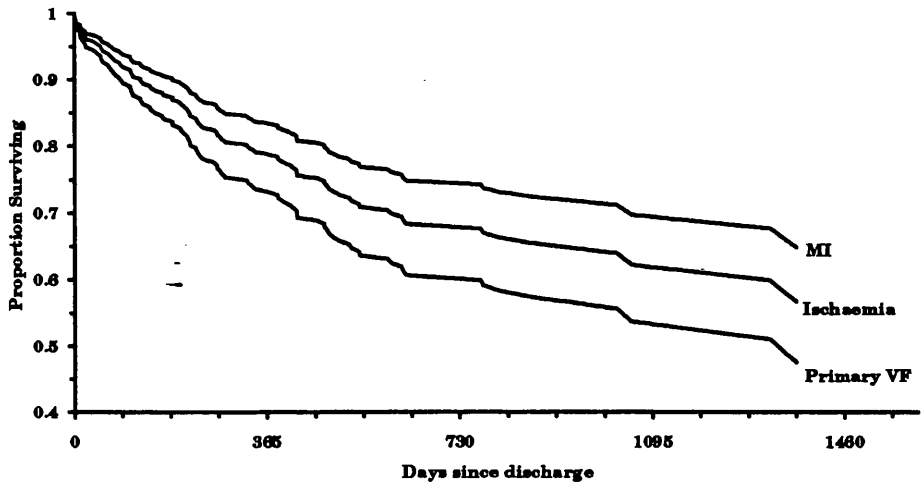

Figure 26 - 65 year old patient, on diuretics and/or ACE Inhibitors

6.5.2.2 Model 2 - Inclusion of arrest type as a categorical design variables

Instead of the inclusion of arrest type as a continuous variable, the model was re-run, assigning two design variables x_1 and x_2 to represent the three arrest types. The values were assigned as

	x_1	x_2
Myocardial Infarction	0	1
Ischaemia	1	0
Primary VF	1	1

As before, age and diuretic/Ace therapy were the first two variables to the model, followed by x_1. Variable x_2 failed the entry criteria at every stage. The log likelihood was only improved by 0.04 in this second model. The model therefore provides no more information than when arrest type was included as a continuous variable. The categories Ischaemia and Primary VF were effectively grouped due to only x_1 entering the model.

One obvious possibility for further analysis would be to stratify the data into arrest due to MI vs. arrest not due to MI but from a clinical aspect the drug treatment of ischaemia patients differs from that of VF patients. It is therefore more relevant to stratify the data by the three distinct arrest types, and look at three independent models thus overcoming the problem of assuming proportional hazards across the three arrest types.

6.5.3 Myocardial Infarction patients.

There were 237 cases for analysis (table 52). Only the drugs relevant to Myocardial infarction were included in the analysis.. At stage 1, Beta-blockers, aspirin and diuretic/ ACE inhibitors fit the entry criteria (table 53). The order of entry was aspirin followed by diuretic/ ACE therapy (table 54). The fitted model had the coefficient values and corresponding standard errors shown in table 55. Interestingly, age does not enter the model for this group. The drug therapy appears to be the best indicator of long-term mortality, specifically aspirin which is associated with an almost threefold reduction in mortality risk.

Total	Died	Survived	Percent Censored
237	40	197	0.8312

Table 52 - Numbers and proportion censored in MI model

Variable	P-Value
Gender	0.7714
Age	0.1394
Hospital Stay	0.4830
Beta-blocker	0.0103
Aspirin	0.0003
Diuretic/ACE	0.0009
Thrombolysis	0.1226

Table 53 - Initial table of p-values to enter in MI model

Step	Variable	P-Value
1	Aspirin	0.0003
2	Diuretic/ACE	0.0079

Table 54 - Order of entry in MI model

Variable	Coefficient	Standard Error	Hazard Ratio
Aspirin	-1.0337	0.3317	0.3557
Diuretic/ACE	0.8755	0.3361	2.4001

Table 55 - Coefficients for MI model

6.5.4 Ischaemia patients

There were 93 cases for analysis (table 56). The fitted model had the coefficient values and corresponding standard errors shown in table 59. At stage 1, only age fits the entry criteria (table 57,58). Drug therapy appears to be unassociated with outcome in the ischaemia model as we found in the univariate PL analysis in section 6.4.2.2. The dominating factor is the age of the patient. There is effectively a doubling of risk ($1.0751^{10}=2.062$) with each 10 year age difference.

Total	Died	Survived	Percent Censored
93	24	69	0.7419

Table 56 - Numbers and proportion censored in ischaemia model

Variable	P-Value
Gender	0.3590
Age	0.0009
Hospital Stay	0.4830
Beta-blocker	0.5214
Aspirin	0.5890
Diuretic/ACE	0.9432

Table 57 - Initial table of p-values to enter in ischaemia model

Step	Variable	P-Value
1	Age	0.0009

Table 58 - Order of entry in ischaemia model

Variable	Coefficient	Standard Error	Hazard Ratio
Age	0.0724	0.0220	1.0751

Table 59 - Coefficients for ischaemia model

6.5.5 Primary VF Patients

There were 85 cases for analysis (table 60). At stage 1, Age and Diuretic/ACE therapy fit the entry criteria (table 61). Once diuretic/ACE therapy has been entered into the model the p value for anti-arrhythmic therapy improves to 0.0765 and makes it eligible to enter the model. Age fails to actually enter the model although it was significant at step 1. Table 62 shows the order of entry. The fitted model had the coefficient values and corresponding standard errors shown in table 63. Diuretic/ACE Inhibitor would appear to be associated with a quadrupling of risk but as we will see in section 6.6 the 95% confidence interval for the hazard ratio is very wide (1.49 , 9.5).

Total	Died	Survived	Percent Censored
85	28	57	0.6706

Table 60 - Numbers and proportion censored in primary VF model

Variable	P-Value
Gender	0.2066
Age	0.0818
Hospital Stay	0.9003
Aspirin	0.6893
Diuretic/ACE	0.0182
Anti-arrhythmic	0.6836

Table 61 - Initial table of p-values to enter in primary VF model

Step	Variable	P-Value
1	Diuretic/ACE	0.0182
2	Anti-arrhythmic	0.0765

Table 62 - Order of entry in primary VF model

Variable	Coefficient	Standard Error	Hazard Ratio
Diuretic/ACE	1.3265	0.4716	3.7678
Anti-arrhythmic	-0.7538	0.4188	0.4706

Table 63 - Coefficients for primary VF model

6.6 Summary of Long Term Survival Analysis

6.6.1 Summary of Product Limit Analysis

The product limit analysis was used primarily to identify which factors might effect the long term survival of the cardiac arrest patients. Significant factors are shown in table 64. Previous MI was not used as a factor in the multivariate analysis due to the number of patients whose previous cardiac history was unknown.

Group	Mantel Cox test statistic significant at 5%
whole group (n=458)	age (<55, 55-64, 65-70, 70+ years)
	Previous MI (Y/N)
cardiac group , n=425	arrest type (MI, Ischaemia, Primary VF)
treatment known group, n=443	Aspirin (Y/N)
	Beta-blocker (Y/N)
	Diuretic/ACE Inhibitor (Y/N)
	Anti-arrhythmic (Y/N)
	Thrombolytic Therapy (Y/N)
arrest due to MI (drug analysis), n=196	Aspirin (Y/N)
	Beta-blocker (Y/N)
	Diuretic/ACE Inhibitor (Y/N)
arrest due to ischaemia-drug analysis, n=93	NS
arrest due to primary VF -drug analysis, n=85	Diuretic/ACE Inhibitor (Y/N)

Table 64 - Summary of product limit analysis

6.6.2 Summary of Proportional Hazards Analysis

In section 6.5 proportional hazards models were generated for all 415 patients for whom treatment details were known and whose arrest was due to a cardiac cause . The data were then stratified by arrest type and three new models were generated for myocardial infarction patients, ischaemia patients and primary VF patients.

The factors of significance in the whole population model were presence/absence of diuretics/ACE inhibitors, age and arrest type. The MI model yielded presence/absence aspirin and presence/absence of diuretics as significant factors. In the ischaemia model age was the only significant variable in the stepwise analysis. Finally in the primary VF model presence/absence of diuretics/ACE inhibitors and presence/absence of anti-arrhythmics were significant factors. It should be noted that in this model the confidence intervals are particularly wide and in fact the 95% interval for anti-arrhythmics is (0.21,1.07), making accurate inferences about the effect of anti-arrhythmic therapy very difficult. Hazard ratios and confidence limits for all four models are summarised in table 65.

Unfortunately splitting the data by arrest type considerably reduced the sample sizes and hence the power of the models to detect effects. Once the number of patients in the study increases a more accurate picture of drugs associated with increased/decreased mortality will emerge

Model (n)	Significant factors	Hazard Ratio	95% CI
Whole Group (415)	Age (10 years)	1.34	1.10 , 1.63
	Diuretics/ACE inhibitor	1.90	1.24 , 2.90
	Arrest Type (1,2,3)	1.31	1.03 , 1.67
Myocardial infarction (237)	Aspirin	0.36	0.19 , 0.68
	Diuretics/ACE inhibitor	2.40	1.24 , 4.64
Ischaemia (93)	Age (10 years)	2.16	1.34 , 3.11
Primary VF(85)	Diuretics/ACE Inhibitor	3.77	1.49 , 9.50
	Anti-arrhythmic	0.47	0.21 , 1.07

Table 65 - Hazard Ratios and 95% CIs for proportional hazards models

6.6.3 Clinical Interpretation of Proportional Hazards Results

In order to make sense of the proportional hazards results, a degree of clinical insight is required. By discussing these results with Professor Cobbe and reviewing the clinical literature, I have identified some important points in aiding their interpretation.

Previous reports[33-35] have emphasised the difference in prognosis between patients with, commonly Q-wave, myocardial infarction and those whose cardiac arrest was not associated with evidence of infarction. It is the latter group who has the worst prognosis, possibly attributable to recurrent ischaemic episodes and/or re-entry arrhythmias associated with myocardial scarring. Patients in this group are associated with a higher prevalence of previous myocardial infarction, severe coronary artery disease and arrhythmias. Although not included in my analysis, previous reports have noted a poorer prognosis in patients with previous MI.

The Cox proportional hazards analysis indicated that cardiac arrest type is not the only independent predictor of survival. Interpretation of the other factors included in the analysis should be carried out with caution bearing in mind the points listed below:-

Age : There may have been a reluctance to submit elderly patients to aggressive investigation and intervention. It may also be argued that age is a surrogate for more extensive coronary disease and/or left ventricular scarring. Young patients are more likely to receive an implantable cardioverter defibrillator (largely primary VF group).

Aspirin : Use was widespread in all categories of patients

Diuretics /ACE inhibitors : In the context of this study the use of diuretics and angiotensin converting enzyme inhibitors should be considered as a marker for clinical evidence of cardiac failure or left ventricular dysfunction . On this basis their association with an adverse prognosis is understandable.

Thrombolytic therapy : The majority of patients receiving this drug were in the Q-wave MI category. The commonest cause given for withholding thrombolytic therapy was prolonged cardiopulmonary resuscitation.

Beta-blockers: Beta-blockade is likely to be withheld from patients with signs and symptoms of heart failure. This may explain the low usage in patients with arrests due to primary VF.

Anti-arrhythmics: Primary VF patients are the group most likely to be treated with anti-arrhythmics.

The management of those patients whose cardiac arrests were due to ischaemia or non-Q-wave MI did not differ markedly from those suffering definite infarction.

CHAPTER 7

Conclusions

7.1 Flogging a Dead Horse?

Most aspects of statistical analysis, pertaining to out-of-hospital cardiac arrest have been covered in this dissertation. There is currently a vast array of academic papers from all over the world on this topic. Only a very small number, however include analysis of the long-term survival of cardiac arrest patients. The majority give a descriptive overview of the EMS system with basic descriptive statistics such as success rates to hospital and subsequently to discharge. These papers are all very similar, having been constructed in the 'Utstein' style[18].

A uniform reporting style is a very sensible idea as it allows international centres to directly compare their results, in a similar way to a multi-centre trial. Success rates can be directly compared and any large discrepancies can generally be explained by comparing the baseline data, such as ambulance response times, type of dispatch system etc. across centres. The limitations of such a system are that :

- Data is 'bottle-necked' into a very specific format, so that interesting data outwith the core data set may be overlooked.
- Data collection centres may feel they must comply with the 'Utstein' guidelines or their results will not be seen as acceptable.
- Many strikingly similar papers are published in journals across the globe, to the extent where the authors almost appear to have 'filled in the blanks'.

It has now been well established that many peoples lives can be saved by the provision of defibrillators in all emergency vehicles. More research should now be carried out on the long-term survival of these patients, as the number of survivors increases. The Heartstart database is certainly one of the world's largest with approximately 10,000 cardiac arrests and 700 survivors identified. Even the analyses carried out in this dissertation are now, to a certain extent redundant. As numbers increase more specific sub-groups can be identified and analysed. The impact of bystander CPR could not be shown significantly until we had around 200 survivors.

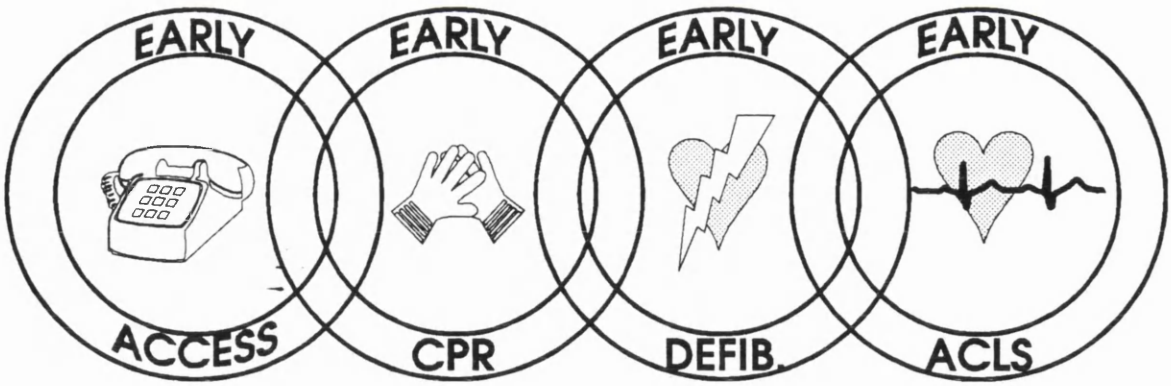

Figure 27 - The chain of survival

The 'chain of survival' (figure 27) is now a well recognised chain of events from the early access link to early advanced cardiac life support. Richard Cummins has published a very consolidated and interesting paper on the subject[11]. Perhaps EMS systems should now be concentrating on improving the early access link and the dispatch system as these appear to be the main areas where deficiencies can be currently identified. Bystander CPR training can be extended to a wider population and the Scottish Home and Health Department together with the Scottish Health Service Advisory Council recently published guidelines from the Scottish working group on cardio-pulmonary resuscitation[36]. They state that first priorities should be (among others):-

- The preparation of overall targets for CPR training should be set out in each health boards local strategy
- Resuscitation committees should be set up, covering all acute hospitals.
- CPR training should be provided to partners/relatives/carers of patients with previous heart attacks
- A national minimum data set should be prepared, for use in audit of cardiac arrest procedures and of deaths from MI in hospitals.

They also lay down guidelines for the inclusion of CPR training within the school curriculum to children as young as 5 years (Recognise emergency and report, open airway.). This would appear be the way forward in terms of improving the current system.

7.2 Lies, Damned Lies and Statistics!

The data collection system was described in some detail in chapter 2. There has always been some doubt as to the completeness of data collected, in terms of recording data on all cardiac arrests where a resuscitation attempt was made. It was not until 1990 that we decided to collect data on non-shocked patients. The idea was that we could calculate the percentage of patients who were in a treatable rhythm on the arrival of the ambulance crew. Unfortunately there is a tendency among ambulance crew members to fill in forms only when they have a success or when the data is required for audit. The ambulance service's own national audit programme only requires data to be collected for defibrillated patients. An improvement is indicated by the increased number of forms collected (figure 28). As the graph reveals the number of shocked arrests increased by 22% in the first year and a further 11% in the second year. The total number has increased dramatically due to the increased collection of non-shocked arrest data.

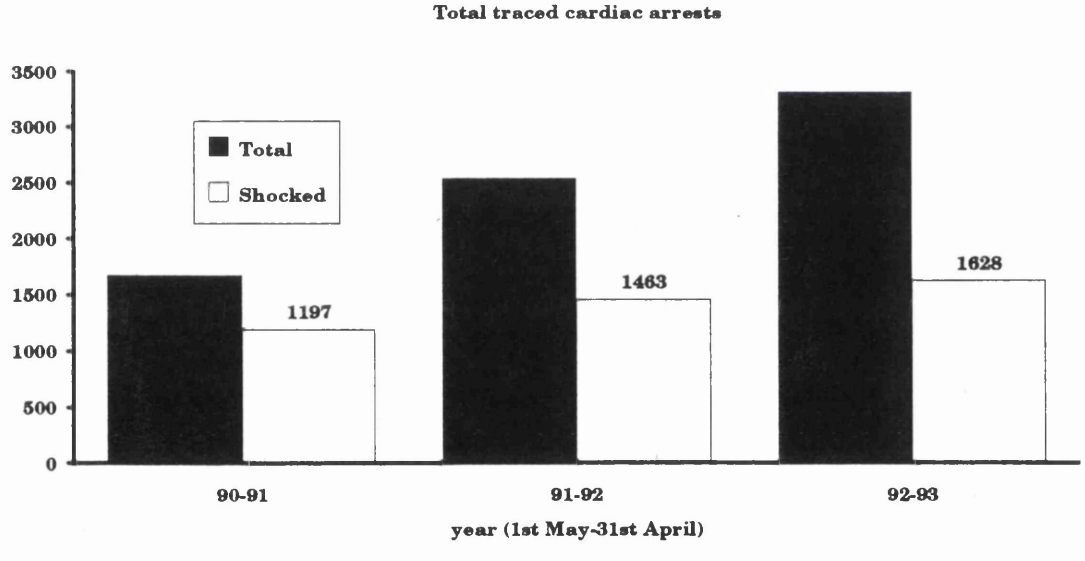

Figure 28 - Increase in number of forms collected 1991-1993

It has taken a great deal of effort to persuade the ambulance crews to complete the forms at all. It is only through communication and strong powers of persuasion that the situation is improving. Feed-back is a crucial factor and it now proposed that a 'league table' of crew

success since the inception of the project is sent to each ambulance station as an incentive to complete the forms. Lists of all crew successes for each station were issued in February 1994 and the feedback was that the crews were delighted to hear how they had performed.

7.3 Current and Future Research Interests

Although many observational studies have been carried out world-wide on initial survival and circumstances surrounding out-of-hospital cardiac arrest, there is still scope for further research. Recently, analysis has been carried out regarding the causative rhythm in out-of-hospital cardiac arrest[37].

7.3.1 Causative Rhythm in Out-of-Hospital Cardiac Arrest

In Scotland we are in the unique position of having ECG data on initial arrest rhythms in cases where the patient arrests in the presence of the ambulance crew. Analysis of 258 rhythm strips revealed that the majority of patients are in VF as their initial arrest rhythm (table 66). 79% of this group had warning chest pain prior to their arrest. This emphasises the need for patients to phone the ambulance on the onset of symptoms so that crews are at the patients side when they arrest increasing the probability of the patient being in a shockable rhythm.

Initial Rhythm	
Ventricular fibrillation	64% (79% with preceding chest pain)
Ventricular tachycardia	4%
Bradycardia	28% (37% with preceding chest pain)
Electromechanical dissociation	4%

Table 66 - Initial rhythm in out-of hospital cardiac arrest

7.3.2 Long Term Survival

As numbers increase and time since the inception of the programme in 1988 increases, analysis of long-term survival will continue to be interesting. There are currently (April '94) 700 survivors to be analysed, some of whom had their initial cardiac arrest nearly 6 years ago. A study of survival in 1998 would provide a far clearer picture of long term

prognosis following resuscitation, even if the data collection is terminated before then. One of the main reasons for continuing to collect data for the duration of the study is to increase the size of the smaller sub-sets of patients, such as crew witnessed arrests and primary VF arrests.

7.3.3 Area Variation

A more detailed look at the variation in response time, arrest to first shock time, proportion of events witnessed by crews, proportion of patients receiving bystander CPR etc. across Scotland's 8 ambulance regions would be useful to both the Scottish Ambulance Service and Scottish physicians. Each area has its own unique relief and population demography. Even within areas there is variety. The Grampian, Orkney and Shetland area for example encompasses islands, rural, semi-rural and urban (Aberdeen) landscapes.

Unfortunately, it is very difficult to make inferences about why the different ambulance regions might exhibit different properties. Part of this difficulty lies in the fact that the quality of ambulance crews and the service they provide is difficult to assess.
From my experience, crews in some areas have a far more positive attitude to form completion than others. As well as examining area variation, annual trends in rates such as the success rate, mortality rate and bystander CPR rate for each area are also of interest.

7.4 Important Statistical Results and Implications

The main statistical analyses were carried out in chapters 5 and 6. Because the overall success rate is relatively low and the number of distinct covariate patterns so large, the predictive power of the logistic regression models in Chapter 5 is poor. I'm not convinced that attaching a survival probability to a patient at any stage is a good thing. It may lead physicians and surgeons to adapt the aggressiveness of their resuscitation attempt, based on the patient's "probability" of survival.

What the regression analyses succeed in doing is identifying those factors that influence survival at each stage in the resuscitation process. Ebell[38] suggested that the cost per patient surviving to discharge increases exponentially as the rate of survival to discharge decreases. Measures must therefore be taken to increase the proportion of patients

surviving to hospital discharge. In real terms (based on my results) the issues that can be addressed in order to improve initial survival are :

- Increasing bystander CPR rates
- In a witnessed collapse : encouraging the general public to call the ambulance first, thus reducing the time from collapse to '999' call
- Encouraging the patient or bystanders to call an ambulance upon the onset of classic "heart attack" symptoms, thus ensuring more arrests are witnessed by crews
- Introduce wider use of AEDs (in sports halls, large shopping centres etc.)

In Chapter 6, long-term survival was investigated. It is clear that patients whose arrest was due to a definite Q-wave myocardial infarction have a better prognosis than those whose arrest was due to some other cause. Survival rates for patients whose arrest was due to ischaemia were similar to those whose arrest were due to primary VF .

Interpretation of drug effects is difficult (see section 6.6.3.). The effect of aspirin is the easiest to interpret as it is prescribed widely. In the myocardial infarction group, aspirin (as an independent predictor) was associated with a decrease in risk of 0.36 . The increased risk associated with diuretics and ACE Inhibitors was thought to be due to their presence being a marker for cardiac failure.

Although the female patients in the Heartstart population are in general older, their survival is no different to that of their male counter-parts. Tresch[39] found that elderly patients have outcomes similar to young patients. The results of my product limit analysis showed significant differences between the youngest patient group (<55 years) and all the three older groups. There were no significant diffrences between survival curves in the these older groups. In the Cox proportional hazards analysis of the whole group (n=415) a 10 year age increase was associated with an increase in risk of 34%. Age was the only independent predictor of risk in the ischaemia model. In this sub-group of 93 patients a 10 year increase was associated with an increase in risk of 116%.

The results in this thesis are in general unsurprising, but they succeed in highlighting the need for improvement in the system , firstly to improve initial survival and subsequently to ensure longevity. Age as a factor cannot be altered, but based on the results here, old patients should be treated as aggressively as their younger counterparts. The introduction of new drug therapies and the availability of implantable cardioverter defibrillators should go some way to improving long-term survival of the resuscitated cardiac arrest patient.

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Appendices

Appendix 1
Number of Ambulances in each Scottish Ambulance Region (1991)

1. Argyll and Clyde	43
2. Ayrshire Arran Dumfries and Galloway	54
3. Fife Lothian and Borders	81
4. Forth and Lanark	41
5. Grampian	49
6. Greater Glasgow	27
7. Highland	63
8. Tayside	37

Appendix 2
Rapid Cardiac Care Form

Scottish Ambulance Service: Rapid Cardiac Care — Form Number [ ][ ][ ] 4

Area _____ [ ][ ][ ] 8
Station _____ [ ][ ] 10
Crew (single=1, double=2) [1 2] 11
Attendant name _____

Defibrillator carried? (yes=1, no=2) [1 2] 12
Episode date Day [ ][ ] Month [ ][ ] Year [ ][ ] 18
Receiving hospital _____ [ ][ ][ ][ ] 23 Hospital A & E No _____

PATIENT DETAILS

Surname
Christian & middle names
Address
Postcode [ ][ ][ ][ ][ ][ ] 30
Patient location (if different from above)
Sex (male=1 female=2) [1 2] 31
Date of birth Day [ ][ ] Month [ ][ ] Year [ ][ ] 37
OR If unknown, approximate age [ ][ ] 39
GP name
GP address
Postcode [ ][ ][ ][ ][ ][ ] 48

PATIENT CONDITION

	Yes	No	
Previous heart history	1	2	47
Previous MI	1	2	48
Previous angina	1	2	49
Chest Pain ? (yes=1 no=2)	1	2	50

If yes, time of onset of pain HR [ ][ ] MIN [ ][ ] 54
Time of call to GP [ ][ ][ ][ ] 58
Time of 999 call [ ][ ][ ][ ] 62
Time of arrival at scene [ ][ ][ ][ ] 66
Time left scene [ ][ ][ ][ ] 70
Time of arrival at hospital [ ][ ][ ][ ] 74
Was monitoring initiated? (yes=1 no=2) [1 2] 75

If yes, reason monitoring initiated:

	Yes	No	
Med. Pract. indicates patient should be monitored	1	2	76
Patient unconscious	1	2	77
Patient recently unconscious eg 'collapse' case	1	2	78
Patient complains of light headedness, dizziness with an abnormally fast/slow pulse	1	2	79
Patient complains of chest pain	1	2	80
Patient with known heart condition	1	2	81

Did patient arrest? (yes=1 no=2) [1 2] 82
If yes, time of arrest HR [ ][ ] MIN [ ][ ] 86

	Yes	No	
Arrest witnessed?	1	2	87
CPR initiated within 4mins of arrest by:			
Bystander	1	2	88
Telephone assisted	1	2	89
Crew	1	2	90
Patient conscious?	1	2	91
Patient breathing?	1	2	92
Patient pulse?	1	2	93
Cardiac drugs used (if yes, specify in comments)	1	2	94
Thrombolytic therapy? (if yes, specify in comments)	1	2	95
Was defibrillation initiated?	1	2	96
Outcome on arrival, Spontaneous pulse	1	2	97
Ongoing CPR	1	2	98
Certified dead	1	2	99

DEFIBRILLATION DETAILS

Joules? _____ [ ][ ][ ] 102
Joules? _____ [ ][ ][ ] 105
Joules? _____ [ ][ ][ ] 108
Pulse? (yes=1, no=2) [1 2] 109
Joules? _____ [ ][ ][ ] 112
Joules? _____ [ ][ ][ ] 115
Joules? _____ [ ][ ][ ] 118
Pulse? (yes=1, no=2) [1 2] 119
Joules? _____ [ ][ ][ ] 122
Joules? _____ [ ][ ][ ] 125
Joules? _____ [ ][ ][ ] 128
Pulse? (yes=1, no=2) [1 2] 129
Joules? _____ [ ][ ][ ] 132
Joules? _____ [ ][ ][ ] 135
Joules? _____ [ ][ ][ ] 138
Pulse? (yes=1, no=2) [1 2] 139

OUTCOME AT 3 MONTHS

Patient known dead (yes=1, no=2) [1 2] 140
If yes, Date of Death Day [ ][ ] Month [ ][ ] Year [ ][ ] 146
Patient known alive (yes=1, no=2) [1 2] 147

If patient arrested, is there a card enquiry number (yes=1, no=2) [1 2] 148 If yes, CARD ENQUIRY NUMBER [ ][ ][ ] 152

COMMENTS

Appendix 3
Scottish Ambulance Service Patient Report Form

SCOTTISH AMBULANCE SERVICE

Patient Report Form

INJURY ASSESSMENT/PRIORITY
1 Critical/Immediate ☐
2 Serious/Urgent ☐
3 Minor/Delayed ☐

Crew | Dr. | Nurse

Date | Call Time

Location | Arrival Time | Surname | Forename

Depart Time | M/F | D.o.b. | Address

Hospital | Arrival Time

TYPE OF INCIDENT RTA ☐ Home ☐ Works ☐ Organised Sport ☐ Leisure ☐ Other (specify) ☐

If RTA Driver ☐ Front/Rear Passenger ☐ Pedestrian ☐ Motor-cyclist ☐ Cyclist ☐

Seatbelts Yes ☐ No ☐ Not Known ☐ Vomited Yes ☐ No ☐ Alcohol Yes ☐ No ☐ Not known ☐

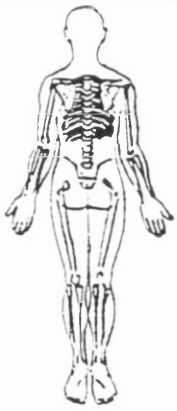
Crash Helmet Yes ☐ No ☐ Not Known ☐ Knocked Yes ☐ No ☐ Trapped Yes ☐ No ☐ Extrication

FOR AIR AMBULANCE ONLY

Turbulence 1 = nil 2 = slight 3 = moderate 4 = severe

Altitude 1 = < 1500 ft 2 = > 1500 ft

OBSERVATIONS	Time	1)	2)	3)
Appearance	Pallid ☐ Cyanosed ☐			
Blood Loss	Slight ☐ Moderate ☐ Severe ☐			
Blood Pressure				
Pulse Rate				
Respiratory	Rate / Sat %			
Convulsing		☐	☐	☐
Eye Opening	Spontaneous 4 ☐ To voice 3 ☐ To pain 2 ☐ Nil 1 ☐			
Best Verbal Response	Orientated 5 ☐ Confused 4 ☐ Inappropriate 3 ☐ Incomprehensible 2 ☐ Nil 1 ☐			
Motor Response	Obeys command 6 ☐ Localised pain 5 ☐ Withdrawal (pain) 4 ☐ Flexion (pain) 3 ☐ Extension (pain) 2 ☐ Nil 1 ☐			
Pupil Scale (mm)	1 2 3 4 5 6 7 8	React R ☐ L ☐ Size R.		



INJURIES
C# Closed Fracture
O# Open Fracture
B Burn (shade area)
F Foreign Body
L Laceration
A Abrasion

Bowel Sounds
☐ Present
☐ Absent

HISTORY/COMMENTS

ACTION TAKEN		Dose/Volume	Time
IV Fluids	☐ Hartmans/N. Saline ☐ Haemaccel ☐ Other (specify)		
Analgesia/ Drugs (specify)	☐ Entonox ☐ ☐ ☐		
Cardiac Arrest	☐ ECM ☐ Defib.		
Airway	☐ Airway ☐ Ventilated ☐ Oxygen ☐ Intubated ☐ Suction ☐ Mini Trac		
Splints	☐ Cx Collar ☐ Frac Straps ☐ Other (specify) ☐ K.E.D. ☐ O.V.S. ☐ Box ☐ Traction		

Signed Crew | Dr. | Nurse

HOSPITAL FOLLOW UP | Hospital No.

Diagnosis A/E

Disposal D.O.A. ☐ Adm. ☐ O.P. ☐ Home ☐

Died | Date | Time

Appendix 4
Cardiopulmonary Resuscitation Report Form

CARDIOPULMONARY RESUSCITATION REPORT

Scottish Ambulance Service : SCOTLAND Serial Number : [ ][ ][ ][ ][ ] 6

If you have a problem filling in this form please refer to the instruction manual.

SECTION 1 : AMBULANCE DATA

Area : _____ Station : _____ [ ][ ][ ][ ][ ][ ] 12
leave blank

Episode Date [ ][ ] Day [ ][ ] Month [ ][ ] Year 18

Attendant Name [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ] 38

SECTION 2 : PATIENT DETAILS

Surname [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ] 58
Forenames [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ] 78

Home Address [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ] 98
[ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ] 118
[ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ] 138
Postcode [ ][ ][ ][ ][ ][ ][ ] 145

Sex [1] Male [2] Female 146

Date of Birth [ ][ ] Day [ ][ ] Month [ ][ ] Year 152

Please fill in approximate age only if date of birth is not known . [ ][ ] 154

Patients own GP [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ] 174
GP Address [ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ] 194
[ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ] 214
[ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ][ ] 234
Postcode [ ][ ][ ][ ][ ][ ][ ] 241

SECTION 3 : PATIENT HISTORY

Previous M.I. ? [1] Yes [2] No [3] Don't Know 242
Previous Angina ? [1] Yes [2] No [3] Don't Know 243
Previous Heart Disease ? [1] Yes [2] No [3] Don't Know 244

If the patient has had previous heart disease please specify.

_____ [ ][ ][ ] 247
leave blank

SECTION 4 : AMBULANCE RESPONSE TIME

Time of 999 (or GP) call [ ][ ]:[ ][ ] 251
Time of arrival on scene [ ][ ]:[ ][ ] 255
Time of arrival with patient [ ][ ]:[ ][ ] 259
Distance travelled from receipt of call to patient (approximately) [ ][ ].[ ][ ] miles 262

SECTION 5 : SEQUENCE OF EVENTS BEFORE ARRIVAL OF AMBULANCE

Was there any Chest Pain during this episode ? [1] Yes [2] No [3] Don't Know 263
If YES, Best estimate of time of onset of pain [ ][ ]:[ ][ ] 267

Was a GP contacted before you arrived ? [1] Yes [2] No [3] Don't Know 268
If YES, Approximate time of call to GP [ ][ ]:[ ][ ] 272

Did the GP attend the scene ? [1] Yes [2] No [3] Don't Know 273
If YES, Was the GP present when you arrived ? [1] Yes [2] No 274

Who contacted the Ambulance Service ? [1] GP [2] Patient [3] Spouse [4] Relative
[6] Bystander [8] Other 275
If other, please state _____ [ ][ ][ ] 278
leave blank

If it was a GP CALL,
Was the call classification : [1] Emergency [2] Urgent 1 hour
[3] Urgent 2 hour [4] Other 279
If other, please state _____ [ ][ ][ ] 282
leave blank

SECTION 6 : ARREST DETAILS

Site of Cardiac arrest: [1] Home [2] Nursing Home [3] Ambulance
[4] Street [5] Work [6] Other 283
If other, please state _____ [ ][ ][ ] 286
leave blank

Probable cause of arrest: [1] Heart Disease [2] Drug Overdose [3] Trauma
[4] Lung Disease [5] Asphyxiation [6] Suicide
[7] Drowning [9] C.V.A. [8] Other 287
If other, please state _____ [ ][ ][ ] 290
leave blank

Did anyone see or hear the patient collapse ? [1] Yes [2] No [3] Don't Know 291
If YES, best estimate of time of arrest [ ][ ]:[ ][ ] 295

Was the Patient Conscious ? [1] Yes [2] No [3] Don't Know 296

Was the Patient Breathing ? [1] Yes [2] No [3] Don't Know 297

Did the Patient have a pulse ? [1] Yes [2] No [3] Don't Know 298

Was CPR started before the arrival of the ambulance? [1] Yes [2] No [3] Don't Know 299

Best estimate of time of start of CPR by first rescuer [ ][ ] 303

Was the rescuer who started CPR :

[1] Ambulance Crew [7] Spouse [8] Other Relative [2] Bystander
[4] Health Personnel [5] GP [3] Police [6] Other 304

If other, please state _____ [ ][ ][ ] 307
leave blank

Was CPR started within 5 minutes of arrest ? [1] Yes [2] No [3] Don't Know 308

Was telephone CPR advice used ? [1] Yes [2] No [3] Don't Know 309

Respiration Support at scene of arrest:

Bag and Mask ? [1] Yes [2] No [3] Don't Know 310

Supplemental 0_2 ? [1] Yes [2] No [3] Don't Know 311

Endotrach. Tube ? [1] Yes [2] No [3] Don't Know 312

Were Cardiac drugs used ? [1] Yes [2] No [3] Don't Know 313

Thrombolytic Therapy ? [1] Yes [2] No [3] Don't Know 314

List any Drugs and doses used : _____ [ ][ ][ ] [ ][ ][ ] 320

_____ [ ][ ][ ] [ ][ ][ ] 326
leave blank

Personnel Attending scene : [1] Ambulance Technician(s) [2] Paramedic(s) [3] Doctor(s) 329

SECTION 7 : DEFIBRILLATION DETAILS

Was the patient defibrillated ? [1] Yes [2] No 330

If YES,

Who initiated defibrillation ? [1] Amb. Crew [2] Medical rapid response unit [3] GP
[4] Paramedic [5] Combination of above or Other 331

If combination or other, please state _____ [ ][ ][ ] 334
leave blank

Time of first Shock [ ][ ]:[ ][ ] 338

Number of Shocks [ ][ ] 340

Time of last shock [ ][ ]:[ ][ ] 344

Defibrillator Type : [1] Laerdal 2000 [2] Laerdal 3000 [3] Marquette [4] Other 345

Defibrillator Mode : [1] Advisory [2] Manual [3] Initially advisory, then manual 346

Is there a printout from the defibrillator to accompany this form ? [1] Yes [2] No 34

If NO, please explain why there is no output ? _____

SECTION 8 : FINAL PATIENT STATUS AT SCENE

Was the patient certified dead at scene of arrest ? [1] Yes [2] No 34

If YES,

Who by ? [1] Patients own GP [2] Other Doctor 34

Time Patient Life Extinct [ ][ ]:[ ][ ] 35

If NO,

Did the patient have a palpable pulse ? [1] Yes [2] No 35

Was on-going CPR being carried out ? [1] Yes [2] No 35

SECTION 9 : OUTCOME DETAILS

Time Left Scene [ ][ ]:[ ][ ] 359

Was the patient taken to hospital [1] Yes [2] No 360

If NO, where was patient disposal : _____ [ ][ ] 362
leave blank

If YES,

Receiving Hospital : _____ [ ][ ][ ][ ][ ] 367
leave blank

Time of arrival at hospital [ ][ ]:[ ][ ] 371

Was the patient certified dead at the hospital ? [1] Yes [2] No [3] Don't Know 372

If YES, time Patient Life Extinct [ ][ ]:[ ][ ] 376

If NO or DON'T KNOW, Condition of patient on arrival at hospital,

Patient Deeply Unconscious ? [1] Yes [2] No [3] Don't Know 377

Patient breathing with spontaneous pulse ? [1] Yes [2] No [3] Don't Know 378

On-going CPR to patient ? [1] Yes [2] No [3] Don't Know 379

Any comments ? [ ] 380
leave box blank

_____

_____

_____

_____

_____

This form has been checked : by Attendant _____ (Signature)

by D.A.O. _____ (Signature)

Appendix 5
Cardiopulmonary Resuscitation Report Form
Instruction Booklet

CONTENTS

INTRODUCTION

This book is intended to help you fill in the Cardiopulmonary Resuscitation Report (CRR) quickly and accurately. Each section in the main body of the booklet directly corresponds to a section of the CRR. This should make it easier to find a solution to any of the problems you might have. There are important points in this booklet and it should be read carefully at least once.

All the information from these forms is input onto a computer database. The data will then be used for statistical analysis and general reference. If you fail to answer certain of the questions on the form, analysis of the results will prove very difficult. To overcome this problem there are a list of checkpoints on the next page that should be read over from time to time to refresh your memory!

GENERAL POINTS TO FOLLOW

1. Please complete forms in **Black Ink.**
2. Complete the form as soon after the event as possible, preferably before the next call out.
3. At that time , or at a later stage if need be, check the entire form to see that nothing has been missed, then sign the form at the bottom of the last page

4. **Most Importantly**:-

a) Make sure there is sufficient information to identify the patient.

b) Make sure the patients age is given, either as a date of birth or approximately. If the **date of birth** is available this is preferable.

c) Ensure that **all** timings are filled in. Most of these can be copied from the log sheet if they are not filled in at the time of the event.

d) i) Boxes can either be ringed or ticked. As long as it is clear which box has been selected it does not matter which method you use.
ii)Make sure that all questions with more than one option have **only one** box ringed.

i.e. Site of Cardiac arrest:

☐ Home	☐ Nursing Home	☐ Ambulance
☐ Street	☐ Work	☐ Other

If other, please state _____ ☐☐☐

e) If the "other" box is ringed, make sure that the following line asking "if other then please state ....." is completed.
This answer should be very brief.

f) If the patient was transported to hospital then check the full hospital name is filled in. Abbreviations are difficult to interpret.

g) Check that nothing has been written in the boxes that say "leave blank" underneath them. These are filled in at a later stage.

h) Forms must under no circumstances be photocopied. If you run out of forms they can be obtained from supplies.

THE CRR FORM SECTION BY SECTION

SECTION 1
AMBULANCE DATA

This section is fairly self explanatory but please make sure the date is entered accurately. The date required is the date you **leave** the patient.

i.e. If you attend a patient before midnight, but by the time the patient is taken to hospital it is after midnight, it is the date the patient arrives in hospital that is required. Correct event date is very important.

N.B. *When writing in boxes, write one letter only in each box. Capital letters are preferable.*

Attendant name

Please write **surname first** followed by **initials**. This is to allow the data to be sorted alphabetically. Leave a space between names.

SECTION 2
PATIENT DETAILS

Patient Name

If there is more than one forename, leave a space between names. If you run out of space don't worry, just stop at the last box. Do not cram the name into the boxes.

Home address

Make sure each part of the address is on a separate line. The postal code is used frequently in analysis so try to obtain it if possible.

e.g.

Home Address :

Postcode:

Don't worry about leaving blank lines in addresses.

Date of Birth

This is extremely important. It helps to identify the patient with Medical Records departments. Only put down an approximate age if the date of birth is **unobtainable**.

GP Details

The same rules apply to the GP details as did to patient name and home address. Please write "Dr" in front of the GP name.

e.g. Patients own GP

SECTION 3

PATIENT HISTORY

If you are at all vague about the patient history, please circle the "Don't Know " boxes. This will improve the accuracy of the results. Make sure that you ring one box for each of the three questions and don't leave any blank.

SECTION 4

AMBULANCE RESPONSE TIME

Most of this information you will have no problem with as you have it already on your log sheets.

Time of 999 (or GP) Call

Always ask Control to give you the **Control receipt of call time**. This may be several minutes earlier than the time they have passed to you.

Time of arrival on scene/ Time of arrival with patient

Where Ambulance Crews R.T. on arrival at scene, that time should be given. The time of arrival with patient may be one or two minutes later (A tall block of flats could cause a 4 or 5 minute time lapse). All timings should be to the 24 hour clock.

Distance from receipt of call to patient

Fill in this distance to the **right** of the three boxes.

e.g. If the distance is eight miles fill the boxes in as | | | |.

Accuracy in this section is **vital**.

SECTION 5
SEQUENCE OF EVENTS BEFORE ARRIVAL OF AMBULANCE

This section is designed to study patient and GP actions. If you answer "yes" to any of the questions please try to answer the subsequent question.

Chest pain

If the chest pain has been present for some time (i.e. more than a day) please state this in the comments section at the end of the form. The time that is required in this section is the time of onset of the pain that lead to the GP or the ambulance being called.

Who contacted the ambulance service?

Only one box should be ringed for questions of this type. If you are in any doubt as to which box to ring then ring the "other" option, and explain on the line below.

SECTION 6
ARREST DETAILS

Site of Cardiac Arrest

Most cases will fall into one of the first five categories. If this is not in fact the case ring box 6 and state the site of arrest as briefly as possible on the line below .
e.g. RTA, Shop, Sports Centre, Golf Course.

N.B. When the patients home address is unknown

The **only** occasion where a full description of location is required is where the patients home address is unobtainable. If this is the case, **no matter what category (1-6)** the site of arrest falls into, write the **precise** patient location on the " If other, please state ..." line of the form.

e.g If other please state _____

Probable cause of arrest

What is wanted here is the primary cause of arrest . If the primary cause of arrest is unknown, ring box 8 and write "unknown" on the line below.

Best estimate of time of arrest

A time is preferable in this section. In some instances it may be easier to ask the relatives or bystanders "How long before you called the ambulance did the patient collapse?", in which case the second section can be filled in. Please ensure that you don't get mixed up between **before** and **after**, when filling in the form, as this could distort the results. If you do fill in the before or after boxes and the time is less than 10 minutes write to the right hand side of the boxes.

e.g. ☐☐ mins before 999 call

When you arrived at the scene

These questions refer to the condition of the patient at the moment you arrive at the scene; i.e. if the patient does not arrest until after your arrival the replies you give may be patient conscious, no CPR etc. If you resuscitate the patient at the scene this will be highlighted **later** in the form. This is very important, so remember:

Condition of patient at the moment you arrive

CPR

Ring the box that refers to the **first** rescuer to give CPR.

Respiration Support

Ring one box for each of the three questions.

Cardiac Drugs

List all drugs and doses administered during the event on the lines provided, taking a new line for each drug.

e.g. _____

_____

_____

_____

Do not write in the boxes to the right of the lines.

SECTION 7

DEFIBRILLATION DETAILS

If the patient was not defibrillated answer only the first question in this section and then go on to section 8.

Who initiated defibrillation?

Here ring the box that refers to the person that **administered the first shock**. This could be the GP who may already have a defibrillator on the scene, so this question does not necessarily refer to the "Heartstart" machines.

Time of first shock/../Time of last shock

If for some reason there is no printout to accompany the form, it is particularly important that you answer these questions

No Printer Output

If there is no output with the form try to be as brief as possible in explaining the reasons. If it is a particular printer that is faulty then state the location of the printer. If someone else has the printout then write down their name.

e.g. _____

SECTION 8

FINAL PATIENT STATUS AT SCENE

It is important to state here whether or not the patient was dead before you left the scene. Make sure therefore that this **whole section** is completed .

SECTION 9

OUTCOME DETAILS

- If the patient was not transported to hospital then only the first two questions have to be answered.
- Make sure you write down the full name of the hospital, otherwise follow-up is impossible.
- It is vital that the 3 questions about :- unconsciousness / spontaneous pulse on arrival / and CPR , are all answered, as these are success indicators .
- Once again, what is important is to make it quite clear what the patients condition was when you left them at the hospital. If you know the patient to be dead and have not stated that anywhere on the form please state that in the comments section.

Any Comments

Only use this section if there is something you have not been able to say anywhere else on the form. It may be that there were unusual circumstances surrounding the event that you wish to elaborate on. If this is the case try to be as brief as possible without detracting from the clarity.

FINALLY

Make sure that the form is checked and signed by the Attendant before handing it over to the District Ambulance Officer to be checked. The printout should be **stapled** to the form.

10 Checks Upon Completion of Cardiopulmonary Resuscitation Report Form

1. Have you written in Black Ink ?

2. Is there enough information to identify the patient ?

3. Have you stapled the printout if there is one, to the form?

4. Have you clearly written the receiving hospital name on the form ?

5. Have all the timings been filled in ?

6. Is the event date on the form the date the patient was admitted to hospital ?

7. Have you read over the form to check that all the appropriate questions have been answered ?

8. Have you made it clear whether or not the patient was defibrillated ?

9. Is it clear what the condition of the patient was when you left the hospital ?

10. If the patient was dead on arrival or not taken to hospital have you made that clear ?

CARDIOPULMONARY RESUSCITATION REPORT FORM

AMENDMENTS

Listed below are the amendments to the yellow CRR form. These should be used in conjunction with the original CRR form instruction booklet. The new form is pink and A4 size. These pink forms should not be used until all the yellow forms have been completed.

SECTION 3 : PATIENT HISTORY

The question 'Previous Heart Failure?' has been amended to 'Previous Heart History?'. If the patient has had any history of heart disease e.g. By-pass Surgery, Heart Transplant, Heart Failure etc. then answer yes to the question and specify on the line below.

e.g. Previous Heart Disease ? ☐ Yes ☐ No ☐ Don't Know

If the patient has had **previous heart disease** please specify,

_____ ☐☐☐

leave blank

SECTION 4 : AMBULANCE RESPONSE TIME

It was found that in many cases it was only 0.5 miles or 1.5 miles that were travelled to the scene meaning that distances would be distorted if rounding took place. The question has therefore been amended to accommodate a decimal point. If the distance travelled is 0.25 or 0.75 then round up to 0.5 and 1 respectively

e.g. Distance travelled from receipt of call to patient (approximately) ☐☐.☐ miles

SECTION 5 : SEQUENCE OF EVENTS BEFORE ARRIVAL OF AMBULANCE

Two extra categories have been added to the section asking who contacted the ambulance service. These are Relative (e.g. Son, Daughter, In-Law) and Bystander (e.g. Workmate, Neighbour, Member of Public)

SECTION 6 : ARREST DETAILS

One extra category has been added to 'Probable cause of arrest'. This is Cerebral Vascular Accident (C.V.A.).

In the 'best estimate of time of arrest' section the minutes before and after '999' call have been deleted as they seemed to lead to confusion, and therefore inaccurate times.

The section asking about CPR has been reworded and extended slightly for a specific reason. The study aims to examine the effect of Early CPR (<=5 minutes from time of collapse) on patient survival. In other parts of the world Early CPR has led to improved survival. As yet we have not proven this to be the case in Scotland. The more specific questions on the new version of the form will possibly lead us to different conclusions. The categories Spouse and Other Relative have been added to the section relating to who started CPR.

Another question has been added to establish what personnel attended the scene of the arrest. More than one option can be ringed.

e.g. Personnel Attending scene ☐ Amb. Technician(s) ☐ Paramedic(s) ☐ Doctor(s)

N.B. All the question in this section relate to 'The scene of the arrest'. i.e. Any care given after hospital admittance is not relevant.

SECTION 7 : DEFIBRILLATION DETAILS

If more than on person administered shocks ring the 'Combination or other' section and specify on the line below.

SECTION 8 : FINAL PATIENT STATUS AT SCENE

This section tries to establish whether or not the patient was certified dead at the scene of arrest. If the patient was not certified dead until hospital then please answer NO to the question 'Was the patient certified dead at scene of arrest?'.

N.B. CRR FORMS SHOULD BE FILLED IN FOR **ALL ARRESTS WHETHER OR NOT THE PATIENT WAS SHOCKED.** THIS IS TO ESTABLISH WHAT PERCENTAGE OF PATIENTS ARE IN A SHOCKABLE RHYTHM WHEN ATTENDED BY AN AMBULANCE CREW.

Appendix 6
Definitions

N.B. Time Intervals are Shown in Bold

Description	Definition
Time of 999 (or GP call)	time emergency call was received by ambulance control (excludes delay due to '999' emergency system)
Time of arrival on scene	time crew call ambulance control to state arrival at locus
Time of arrival with Patient*	time of arrival at the side of the patient
Response time	999 call to arrival on scene
Best estimate of arrest time	time witnesses saw or heard the patient collapse
Best estimate of start of CPR	time any form of CPR was initiated by a bystander
Time of first shock*	time defibrillator MCM registers first shock
Arrest to first shock time	time patient is reported to have arrested until first shock time
Time left scene	time crew leave locus
Time of arrival at hospital	time crew arrive at A&E department
Journey time	time left scene to arrival at hospital
Time PLE	time patient certified dead (life extinct)
Time of onset of chest pain	time pain chest pain presented (if earlier in same day)
Time of call to GP	time patient or relatives made call to GP

* Applies only to forms completed after April 1991

** Applies only to pink form

Appendix 7
Two Clinical Details Forms

SCOTLAND

PATIENT DISCHARGE FORM

Patient Name : Date of Birth : ___/___/___

Address .....

..... Postcode ☐☐☐☐☐☐☐

Hospital : Admission Date : ___/___/___

Consultant : Ward :

Date of Discharge or Death : ___/___/___ Home / Acute Hospital / Long Stay/ Died

If Acute Hospital or Long Stay - Name.....

Type of Arrest

Uncertain ☐

Cardiac ☐ Answer 1-3 Proven AMI :1- Q Wave, 2- Non Q Wave, 3- MI Unspecified

☐ Old MI ☐ Ischaemia ☐ Other Cardiac

Non Cardiac ☐ Cause Suspected:.....

Management at Discharge (tick all those applicable)

1. ☐ Thrombolytic Therapy

2.

☐ Unknown	☐ No Therapy	☐ Beta Blocker
☐ Other Anti Ischaemic	☐ Referred for Cor. Angio	☐ Referred for EPS
☐ Aspirin	☐ Anticoagulants	☐ Diuretics
☐ ACE Inhibitor	☐ Antiarrhythmic- Specify.....	
☐ 24hr ECG	☐ Exercise test	☐ Other - Specify.....

Outcome

☐ Conscious and normal	☐ Conscious - Moderate Disability
☐ Conscious - Severe Disability	☐ Coma or Vegetative State
☐ Brain Dead or Dead	☐ Neurological Status Unknown

Has the Patient died since discharge ? ☐ Yes ☐ No

If Yes, Date of death : ___/___/___

Place of Death .....

If Dead, Cause of Death ICD CODES

I .....

..... ☐☐☐☐☐☐

II .....

..... ☐☐☐☐☐☐

Heartstart Number : ☐☐☐☐☐☐

Heartstart Scotland Patient Discharge Form (2)

Heartstart Number : ☐☐☐☐☐☐

Discharge Diagnosis

	Hospital	SMC
Myocardial Infarction	☐	☐
Ischaemia	☐	☐
Primary VF	☐	☐
Other	☐	☐
Inadequate Information	☐	☐

Previous M.I. ? ☐ Yes ☐ No ☐ Unknown

ECG Description

Bradycardia	☐		
Old Q Waves	☐	New Q Waves	☐
ST elevation	☐	ST depression	☐
T Wave Changes	☐	LVH	☐
L.B.B.B	☐	Bifascicular Block	☐
"Sequential Changes"	☐	Nil Significant	☐
Not Available	☐	Complete Heart Block	☐

Enzymes

	> 2x	1-2x	Normal	"Elevated"	N/A
CPK	☐	☐	☐	☐	☐
CK-MB	☐	☐	☐	☐	☐
AST	☐	☐	☐	☐	☐
LDH	☐	☐	☐	☐	☐

Type of Arrest (SMC)

Cardiac
- ☐ Proven Acute Q Wave M.I.
- ☐ Proven Acute Non Q Wave M.I.
- ☐ Proven Acute M.I. - ECG Unspecified
- ☐ Old M.I.
- ☐ Acute Ischaemia
- ☐ Presumed IHD - Inadequate Details
- ☐ Non-Ischaemic

Non-Cardiac ☐ Cause Suspected _____

Uncertain ☐