"Heartstart Scotland"—initial experience of a national scheme for out of hospital defibrillation

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Abstract

Objective—To determine the outcome of out of hospital defibrillation in Scotland during the year after the introduction of automated external defibrillators in October 1988.

Design—Retrospective analysis of ambulance service reports and hospital records.

Setting—Scottish Ambulance Service and acute receiving hospitals throughout Scotland.

Main outcome measures—Delay from cardiac arrest to first defibrillator shock; vital state on arrival at hospital accident and emergency department; survival to hospital discharge.

Results—During the study period 268 defibrillators were purchased by public subscription and 96% of the 2000 ambulance crew underwent an eight hour training programme in cardiopulmonary resuscitation and defibrillation. A total of 1111 cardiac arrests were recorded, and defibrillation was indicated and undertaken in 602 (54%) patients, mean age 63 (range 14-92) years. A spontaneous pulse was present on arrival at hospital in 180 (30%) of the defibrillated patients, and 75 (12.5%) were subsequently discharged alive. As expected, the likelihood of survival was inversely related to the delay from the onset of cardiac arrest to the time of the first shock and was greater in the case of witnessed arrest. If ventricular fibrillation occurred after the arrival of the ambulance, survival to discharge was 33%.

Conclusions—An effective scheme for out of hospital defibrillation can be introduced rapidly, and with limited training implications and costs, by the use of automated external defibrillators in ambulances.

Introduction

Although the feasibility of out of hospital defibrillation was first shown in 1967 in Belfast,¹ the widespread provision of this service elsewhere in the United Kingdom has been slow to develop. An early randomised study of prehospital coronary care suggesting no improvement in survival² may have been responsible in part for the official decision in 1976³ not to support this development. It is noteworthy that the scheme in question failed to achieve any survivors from prehospital cardiac arrest. Many successful schemes have, however, been developed elsewhere in the world⁴⁻⁶ and in the United Kingdom.⁷ In one well organised scheme in Seattle, Washington, 1648 victims of out of hospital cardiac arrest were resuscitated and left hospital alive over a 13 year period.⁸

The common feature of all successful programmes for out of hospital resuscitation has been the use of decentralised emergency services (fire, ambulance) to provide rapid response. Ambulancemen or paramedics have been trained to various levels of expertise in basic

Characteristics of automated external defibrillator

Software algorithm based on ECG digitised at 10 ms intervals

ECG segments of 3 s length analysed for:

- (1) Treatable rhythm: ventricular fibrillation >100/min or ventricular tachycardia >180/min with peak to peak amplitude >0.1 mV
- (2) No treatable rhythm
- (3) Noise
- (4) Asystole

Modes:

- (1) Monitoring—if three out of four analysis intervals indicate treatable rhythm, audible signal "check patient" is given
- (2) Analyse—after analyse key is pressed, if one out of two analysis intervals indicate treatable rhythm the message "shock indicated" is given, and charging starts automatically
- (3) Shock—200 J or 320 J may be selected; manual initiation of discharge

and advanced life support in such schemes. The Department of Health and Social Security in 1984⁹ reversed its previous stance and authorised the extended training of ambulance crew in defibrillation, intubation, intravenous infusion, and drug therapy under the aegis of the National Health Service Training Authority.¹⁰ Until recently however, no additional resources were made available for this initiative, and the costs of extended training have resulted in the slow and piecemeal development of advanced prehospital resuscitation.

Analysis of the types of patients requiring prehospital treatment needing advanced skills has suggested that the lifesaving impact of defibrillation is likely to be substantially greater than that achieved by endotracheal intubation or treatment with intravenous drugs or fluids.¹¹ A complementary approach to the introduction of full extended training is therefore to train ambulance crew in defibrillation only. With the availability of automated external defibrillators that analyse the electrocardiogram¹² it is not necessary to train ambulance crew extensively in electrocardiographic diagnosis. The Scottish Ambulance Service therefore decided in 1988 to adopt a policy of introducing defibrillators into all of its front line vehicles, providing limited training of all vehicle crew in the use of automated external defibrillators. We report the results obtained in the first year of this project (October 1988 to September 1989).

Methods

Organisation—Before 1988 the Scottish Ambulance Service had only a handful of staff trained as para-

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medics. Apart from a limited trial in north east Fife, which proved the model subsequently used throughout Scotland, there was no scheme for prehospital defibrillation. The ambulance service decided, in conjunction with a medical advisory group, to institute a programme of training of all vehicle crew in defibrillation only, rather than adopt the slower and more expensive option of training vehicle crews according to the full guidelines of the NHS Training Authority.¹⁰ In the absence of NHS funding for the purchase of defibrillators at that time a fundraising appeal, Heartstart Scotland, was launched jointly with the British Heart Foundation. The objective was to raise £2.25m to equip all 407 ambulances and operational support vehicles in Scotland with a defibrillator and to provide the associated training mannequins, maintenance, and consumables.

Equipment—The Laerdal Heartstart 2000 automated external defibrillator is a portable battery powered device weighing 10 kg. Characteristics of the machine are shown in the box. Monitoring may be performed by conventional self adhesive electrocardiogram electrodes in patients who have a spontaneous rhythm, or

through 12 cm diameter self adhesive defibrillation pads if cardiac arrest has occurred.

Training—Ambulance crews were trained in defibrillation in groups of six crew per teacher. Instruction was performed by ambulance training officers without direct medical supervision; the protocol, standing orders, and training scheme had been medically approved. The eight hour session included four hours of revision in basic cardiopulmonary resuscitation plus four hours of practical tuition in the use of the defibrillator. Resuscitation mannequins (Laerdal Skillmeter Resusci-Anne and Mini-Heartsim) were used for training in cardiopulmonary resuscitation and defibrillation.

Treatment protocol—Ambulance crew were instructed to verify cardiac arrest by the presence of unconsciousness and apnoea and absence of a pulse. While one crew member started cardiopulmonary resuscitation the other switched on the defibrillator, attached the large defibrillator pads, and pressed the "analyse" control on the defibrillator. If a treatable rhythm is present, the machine issues an audible signal—"check patient"—to remind the crew to verify the signs of cardiac arrest. Continuing presence of a treatable rhythm results in automatic charging of the defibrillator. Once the capacitors are charged, an audible "stand back" warning is given. The ambulance crew must press the "shock" button to deliver the shock. If a cardiac arrest occurs during continuous monitoring with the small electrodes, the presence of a treatable rhythm will elicit the signal "check patient"; the crews were instructed to change to the large defibrillator pads to analyse and to deliver a shock. A strict protocol, summarised in figure 1, was taught. The importance of maintaining effective cardiopulmonary resuscitation at all times other than during analysis of the rhythm and the delivery of shocks was emphasised, as well as the importance of observing physical signs. Delivery of a shock to a conscious patient or one with a palpable carotid pulse was expressly forbidden, regardless of the machine's recommendation. A maximum of 12 shocks was permitted.

Evaluation—An evaluation subcommittee was established by the Scottish Ambulance Service under the chairmanship of a cardiologist (SMC); it included the chief ambulance officer responsible for the Heartstart Scotland scheme (DJC). All ambulance crew in Scotland performing cardiac monitoring or attempting resuscitation were instructed to complete a form that requested details on patient identification, circumstances surrounding cardiac arrest, response times, details of the resuscitation attempt, and outcome defined as the presence of a spontaneous pulse on arrival at hospital. Further details of the resuscitation attempt were obtained from the memory module fitted into the defibrillator that recorded the electrocardiographic rhythms at the time of analysis, the timings and energy of shocks given, the transthoracic impedance, and the electrocardiogram following the shock. Further follow up of patients in whom defibrillation was attempted was undertaken by a research nurse (MJR), who requested details from the receiving hospital on all patients arriving at accident and emergency departments with a spontaneous pulse. Patients were classified as dead on arrival, died in the accident and emergency department, died in a hospital ward, or discharged alive.

Statistics—Data are presented either as mean (95% confidence interval) or median (interquartile range and full range) as appropriate. Categorical variables were analysed with the χ^2 test with Yates's correction. Differences between groups were assessed by the unpaired Student's *t* test or Mann-Whitney U test as appropriate.

FIG 1—Abbreviated protocol contained in the case of each defibrillator. It was supplemented by detailed standing orders

Results

Between 1 October 1988 and 30 September 1989 funds were raised to purchase a total of 268 defibrillators, and a total of 5548 "defibrillator weeks" were available for study. Fundraising since September 1989, plus a donation of 22 defibrillators from the Scottish Home and Health Department, completed provision of the 407 defibrillators currently required. Training of 96% of the 2000 vehicle crew was completed by July 1989.

During the study period a total of 6706 forms were received in respect of patients monitored or defibrillated by crews of ambulances equipped with defibrillators. In all, 1111 cardiac arrests were reported; the defibrillators indicated a treatable rhythm and one or more defibrillator shocks were delivered in 602 cases (54%). Survival data were obtained in all these cases (table I), although data on timings and other details were often incomplete. There were 75 survivors to hospital discharge, representing a survival rate of 12.5% (95% confidence interval 5.9% to 19.1%) of patients defibrillated, and 6.8% (1.7% to 11.8%) of all patients in cardiac arrest. Data on survival to hospital discharge are not available for the 509 patients who did not undergo defibrillation, but previous studies found virtually no survivors of out of hospital cardiac arrest except when arrest was caused by ventricular tachyarrhythmias.^{4,6} The mean age of patients defibrillated was 63 (range 14-92) years with a male to female ratio of 2.7:1. There was no significant difference in mean age or in sex distribution between survivors and non-survivors.

Most of the cardiac arrests in which defibrillation was attempted were witnessed (67%, 401/602), and, as expected, the survival rate was higher in witnessed than in unwitnessed arrests (14% v 7%, table II).

TABLE II—Outcome in witnessed and unwitnessed cardiac arrests

Outcome	No (%) witnessed	No (%) unwitnessed	Unknown
Survived	56 (14.0)	12 (6.7)	7
Died	345 (86.0)	167 (93.3)	15
Total	401	179	22

$\chi^2 = 5.62$, $df = 1$, $p = 0.018$.

Seventy eight of the witnessed cardiac arrests occurred after arrival of the ambulance crew or during transport to hospital. The survival to discharge in this group was 33% (26/78). The time elapsed from estimated onset of cardiac arrest to delivery of the first shock was calculable in 277 cases, and in these cases it was the most significant predictor of outcome (fig 2). The median time from cardiac arrest to delivery of the first shock was 3 minutes (interquartile range 1-6, range 0-22) in survivors, and 11 minutes (6-7, 0-83) in non-survivors ($p < 0.001$). The survival rate was 15% (44/285) in cases where the timings were recorded, and

FIG 2—Elapsed time from estimated onset of cardiac arrest to delivery of first shock. Survival was significantly associated with early defibrillation ($p < 0.001$)

10% (31/317) in those with incomplete data, of which a greater percentage was unwitnessed. Significantly fewer shocks were delivered in survivors (median 2, range 1-12) than in non-survivors (3, 1-14).

Cardiopulmonary resuscitation was attempted by bystanders in 45% of the 519 cardiac arrests for which data were recorded. The overall survival rate was not significantly increased by bystander cardiopulmonary resuscitation, being 12% (28/232) when it was attempted and 10% (29/287) when it was not. Analysis of 237 witnessed cardiac arrests for which complete data on timing and attempted cardiopulmonary resuscitation were available suggested no benefit from resuscitation in the group defibrillated within five minutes, but there was a trend towards benefit in the group in which defibrillation was delayed (table III).

TABLE III—Time between cardiac arrest and resuscitation attempt related to survival of patient in 237 arrests for which full timing data were recorded by automated external defibrillators

	No (%) given resuscitation	No (%) not given resuscitation
<i><5 Min from arrest to first shock</i>		
Survived	6 (46)	16 (46)
Died	7 (54)	19 (54)
Total	13	35
$\chi^2 = 0$, $df = 1$, $p = 1.0$		
<i>>5 Min from arrest to first shock</i>		
Survived	8 (8)	4 (4)
Died	87 (92)	90 (96)
Total	95	94
$\chi^2 = 0.77$, $df = 1$, $p = 0.38$		

The median journey time from the site of resuscitation to the receiving hospital was 8 minutes (interquartile range 4-15, range 1-89) in survivors and 7 minutes (5-11, 0-75) in non-survivors. The percentage of resuscitation attempts performed less than five minutes' journey time from hospital was 33% for survivors and 23% for non-survivors.

Discussion

This is the first study to report on the widespread introduction of automated external defibrillators into an ambulance service. These devices have allowed very rapid introduction of out of hospital defibrillation and show that a substantial number of successful resuscitations can be achieved by a scheme in which the individual training requirement was as little as eight hours.

Although the provision of a full range of paramedical skills such as intubation and treatment with intravenous drugs and fluids in addition to defibrillation is regarded as the optimum in out of hospital resuscitation, it has not proved economically or operationally feasible in most communities to train all "first responders" to this level. The Seattle scheme initially comprised a first tier emergency medical technician trained in basic cardiopulmonary resuscitation and supported by a second tier of paramedics fully trained in advanced cardiac life support.⁸ Even within that scheme it was shown that improved survival can be achieved if the first responder is able to defibrillate.¹³

Other communities have adopted single tier systems in which the first responders have been trained in basic cardiopulmonary resuscitation and defibrillation but do not have paramedical skills. The addition of defibrillation to basic resuscitation skills increased annual survival from cardiac arrest in communities in rural Iowa from 1.4 to 8.3 per 100 000.¹⁴ Table IV compares the results of the present scheme with those of similar schemes.¹⁴⁻²⁰ The overall proportion of patients in ventricular fibrillation and the survival rate after defibrillation in the present study are comparable

TABLE IV—Previous studies of outcome of defibrillation

Location	Date	No of attempted resuscitations	Patients in ventricular fibrillation		
			No (%) of arrests	No (%) discharged	Type of defibrillator
King County, Washington ¹⁵	1980	54	38 (70)	10 (26)	Manual
Iowa ¹⁴	1984	110	64 (58)	12 (19)	Manual
Stockholm ¹⁶	1987	307	144 (47)	9 (6)	Manual
Nottingham ¹⁷	1987	403	253 (63)	35 (14)	Manual
Minnesota ¹⁸	1988	100	51 (51)	6 (12)	Advisory or automatic
Stockport ²⁰	1989	103	70 (68)	15 (21)	Advisory or automatic
Total		1077	620 (58)	87 (14)	

to previous reports of resuscitation largely based on manual defibrillators. Training programmes have previously required instruction of ambulance crew in recognising ventricular tachycardia and fibrillation on electrocardiograms, with training courses varying from 8 to 96 hours.¹⁴⁻¹⁷ To retain skills, ambulance crew need regular refresher training.¹⁴ Studies from well established emergency care programmes have indicated that the survival rates after fully automatic external defibrillators were introduced were comparable with, and indeed slightly superior to, those achieved with manual defibrillators.¹²⁻²³ The introduction of automated defibrillators with a sensitivity and specificity in identifying ventricular fibrillation equal to that of trained paramedics has noticeably reduced the costs of training and retraining staff, without significant increases in equipment costs. The type of device used in the present study maintains the safeguard that the ambulance crew have to initiate the shock, which minimises the risk of delivering inappropriate shocks should the device misinterpret the rhythm. As we have shown, the use of automated external defibrillators allow a defibrillator service to be introduced rapidly. By a simple comparison, the 16 000 hours of training required in this scheme (8 × 2000) would have allowed only 60 ambulance staff to be released for the extended training recommended by the NHS Training Authority.¹⁰

The delay from cardiac arrest to defibrillation was the most important determinant of survival in this series, as in all previous studies. Similarly, the superior survival in witnessed cardiac arrests was not unexpected. The apparent failure of bystander cardiopulmonary resuscitation to improve outcome was surprising and disappointing: although it was attempted in 45% of cases, it seems to have been inadequate to influence survival, although a trend towards benefit was evident when defibrillation was delayed for more than five minutes. It is noteworthy that apart from one television series, which was not scheduled at peak viewing time, there has been little attempt at public education in cardiopulmonary resuscitation in Scotland.

A previous theoretical study of the impact of paramedical skills on survival of patients transported by ambulance estimated that 250 successful resuscitations to hospital discharge might be achieved in Scotland each year.¹¹ The results of the present study indicate a survival rate of 75 patients during 5548 "defibrillator weeks." Once all ambulances are equipped, an annual total of 21 164 defibrillator weeks (407 × 52) will be available, leading to a projected 286 successful resuscitations a year, a figure consistent with the previous estimate. If it is assumed that out of hospital resuscitation will provide useful benefits only in people under 75 then the possible impact of resuscitation may be estimated. The annual report of the Registrar General for Scotland indicated a total of 7190 deaths in men and women from ischaemic heart disease in 1989 from a population of 4 764 692 aged under 75.²⁴ The effect of 286 successful resuscitations would thus be equivalent to a reduction of 6.0/100 000

annually—a 4% reduction in deaths from ischaemic heart disease. Although this may seem a small figure, it has been estimated that resuscitation before the patient reaches hospital may contribute more to the decline in coronary mortality in the Western world than other established treatments, such as treatment of hypertension, coronary care units, and coronary artery bypass grafting.²⁵

In summary, this study indicates that a widespread scheme for prehospital defibrillation can be introduced in a matter of months without major training costs, provided that funds are available for buying automated external defibrillators. The results achieved are encouraging, and they are comparable to those of long established emergency care programmes.

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