Audit of paediatric cardiopulmonary resuscitation

P A Innes, C A Summers, I M Boyd, E M Molyneux

Abstract

The causes and outcome of cardiopulmonary arrests were studied in a paediatric hospital over a 12 month period. Forty five resuscitation attempts were made involving 41 children and one adult. Twenty eight (68%) of the children were under 1 year of age and 10 (24%) were neonates. Twenty one (47%) arrests were primarily respiratory and 11 (24%) primarily cardiac in origin. Eighty two per cent of the respiratory arrests had an initially successful outcome, compared with 36% of the cardiac arrests. Overall 70% of cardiopulmonary resuscitation attempts were initially successful. There were no survivors from resuscitation attempts longer than 30 minutes.

At 12 months after cardiopulmonary resuscitation 15 (37%) of the children were still alive. The 11 children who had been neurologically normal before the arrest showed no evidence of neurological damage after successful cardiopulmonary resuscitation.

(*Arch Dis Child* 1993; 68: 487–491)

Paediatric cardiac and respiratory arrests are not common. The causes are varied and the outcome is often poor.[1] Eisenberg *et al* in Seattle, in a retrospective survey of arrests, found an incidence of 12·7/100 000 in children under 18 years of age.[1] These figures included arrests before admission to hospital of which 33% were due to sudden infant death syndrome, most of whom would not have received resuscitation. Of the attempts to resuscitate 6% survived.[1] In a five year retrospective study in rural America there were only three survivors of 70 children with cardiopulmonary arrest. In 25 in respiratory arrest alone there were 21 survivors, however.[2] In Europe Stopfkuchen *et al* found that of 149 children requiring cardiopulmonary resuscitation 21% survived to leave hospital, but five had severe neurological damage.[3] Barzily *et al*, who studied the outcome of cardiopulmonary arrests in 69 children, found that if resuscitation took less than five minutes 54% survived instead of 5%. If only one dose of adrenaline had to be given before recovery, the chance of survival improved from 0 to 38%.[4]

Comparable treatment protocols are used in resuscitation in North America, Europe, and the United Kingdom but published studies of paediatric cardiopulmonary resuscitation in hospitals in the United Kingdom with which to draw comparisons are few. In the BRESUS study of 3765 cardiopulmonary resuscitation attempts in 12 British hospitals there were 48 children under 14 years of age; eight survived to one year (two were lost to follow up).[5] No causative details are given. The effectiveness of resuscitation in children has not been subjected to the same scrutiny in Britain that adult cardiopulmonary resuscitation has received. Consequently a standard of good practice in terms of outcome is not established in this country.

This study was undertaken to evaluate the causes of cardiopulmonary arrest in a large paediatric hospital, the response to these by the 'crash team', and the final outcome of attempts at cardiopulmonary resuscitation.

Subjects and methods

The Royal Liverpool Children's Hospital, Alder Hey, is a 344 bed paediatric hospital serving the local population of Liverpool and some of the surrounding districts, but also has a number of supraregional paediatric units which include a burns unit and cardiothoracic and neonatal surgical units. The accident and emergency department sees 55 000 new patients a year. There are two intensive care units, one for general and the other for cardiac patients. The crash team covers all areas of the hospital with the exception of the intensive care units which manage their own emergencies. The team consists of the on call medical paediatric registrar and senior house officer, the anaesthetic registrar, a nursing officer, and a porter. During working hours an electrocardiogram technician attends, and between 8 am and 8 pm an operating department assistant also forms part of the team. All members of the team are alerted simultaneously via the hospital bleep system.

The hospital has a resuscitation committee consisting of consultants in paediatric anaesthesia, accident and emergency medicine, and cardiology, nursing staff from these specialties, a senior operating department assistant, a senior pharmacist, and a representative of hospital management. An anaesthetic registrar and accident and emergency registrar who attend arrests are co-opted on to the committee. This meets monthly to discuss any cardiopulmonary resuscitation events of the previous month, and attempts to highlight and deal with any deficiencies.

At the time of the study there were no formal protocols for the management of cardiopulmonary arrests. Resuscitations were managed according to recommendations by the Resuscitation Council.[6]

On each ward and in each treatment area of the hospital there are drug boxes and resuscitation equipment. The equipment in the boxes is described in the appendix. There are 41 sealed boxes throughout the hospital, each containing paediatric and adult equipment. The contents of each box are checked every two weeks. Each box is replenished immediately after use. In the accident and emergency department, resuscitation equipment is kept in readiness on a resuscitation trolley. Resuscitation drug boxes are kept with the equipment boxes.

Departments of Anaesthesia and Accident and Emergency Medicine, Royal Liverpool Children's Hospital
P A Innes
C A Summers
I M Boyd
E M Molyneux

Correspondence to:
Dr Molyneux, Department of Accident and Emergency Medicine, Royal Liverpool Children's Hospital, Alder Hey, Eaton Road, Liverpool L12 2AP.

Accepted 7 December 1992

Senior house officers are instructed in paediatric resuscitation by consultants in accident and emergency and anaesthesia. Other medical staff receive no formal training. Nursing staff are taught paediatric resuscitation during their training course and in an ongoing programme for trained staff. At the time of the study other hospital staff were not involved with this programme.

From 1 April 1990 to 31 March 1991 all resuscitation attempts made at the Royal Liverpool Children's Hospital by the crash team were studied. Immediately following a cardiopulmonary resuscitation attempt the medical or anaesthetic registrar present completed a questionnaire about the event. Details recorded include the age, weight (actual or estimated), and sex of the child; the site of arrest, the grade of staff who was first on the scene and alerted the crash team, and the staff who responded to the call. A record was kept of the drugs used during resuscitation, the size of endotracheal tube needed, and the ease of intubation. If direct current shock was used this was noted together with the number and amplitude of shocks given. The initial diagnosis of the child together with any relevant medical history was described briefly. The duration of the cardiopulmonary resuscitation attempt and its outcome were recorded. Any difficulty with equipment or the smooth running of the resuscitation event were reported.

Completed questionnaires were returned to the investigators who analysed the data. Patients were followed up by case note review; for patients who died a postmortem examination was performed when possible. Clinical review continued for 12 months for survivors. All available information was used to define the cause of arrests. Casenotes of survivors were reviewed and their family practitioners contacted to try to identify any evidence of residual neurological or developmental problems.

Results

During the year there were 63 arrest calls via the hospital switchboard, of which 46 required attempts at resuscitation. Seventeen calls required no resuscitative actions and are excluded from analysis. Most of these calls were to children with prolonged apnoea or epileptiform fits. There were a further two episodes requiring resuscitation to which members of the team were called individually. From this total of 46 resuscitation attempts, 45 questionnaires were completed and returned. These cardiopulmonary arrests occurred in 41 children and one adult. One girl had two arrests and a boy three arrests. These children had severe and chronic respiratory problems and on each occasion required periods of assisted ventilation. The adult was a visiting grandfather who had a fatal myocardial infarction. Of the children, 23 were boys and 18 were girls.

Twenty eight (68%) of the children were under 1 year of age and almost half of these had a postconceptional age of less than 44 weeks. Seven children were aged 1 to 3 years, three children were between the ages of 3 and 10 years, and three between 10 and 16 years of age. Body weights ranged from 1·3 to 66 kg. Sixteen arrests took place on medical wards. Ten children required resuscitation in accident and emergency, though seven of the 10 arrests managed there originated outside the hospital (table 1). Approximately equal numbers of arrests happened at day and night, 22 (49%) of the arrests occurring between the hours of 8 pm and 8 am. The first person to be at the scene of an arrest and to alert the crash team was a member of the nursing staff on 40 occasions (89%).

The causes of the arrests were various. Eleven were thought to be primarily of cardiac origin, 21 respiratory, four drug related, four sepsis related, three due to hypovolaemia, and one caused by hypoglycaemia (table 2). All cases required ventilatory assistance and 26 required cardiopulmonary resuscitation with cardiac massage.

MANAGEMENT

All children received assisted ventilation by bag and mask but airway control required endotracheal intubation in 30 (67%) cases. In every case that it was thought that endotracheal intubation was required, it was achieved. This was usually performed by the anaesthetic registrar, but five children arrived in the accident and emergency department having already been in-

Table 1 Site of resuscitation attempt

Location	*No of cases*
General medical wards (total 8)	16
General surgical wards (total 8)	7
Cardiac wards (total 2)	4
Neonatal surgical unit	6
Accident and emergency department	10*
Ambulance	1
Corridor	1

*Seven arrests originated outside hospital.

Table 2 Underlying causes of arrests

Cause	*No of cases*
Cardiac	
Myocardial disorder	2
Failed pacing	1
Critical aortic stenosis	2
Cardiomyopathy	1
Myocarditis	1
VSD and PDA*	1
Pulmonary oedema	2
Ischaemic heart disease	1
Respiratory	
Prolonged apnoeas	5
Postictal apnoea	4
Bronchospasm	2
Laryngospasm	1
Croup	1
Inhaled foreign body	1
Laryngeal oedema after burns	1
Viral pneumonitis	1
Aspiration	3
Pneumonia	2
Pleural effusions	1
Drug induced	
Opiates	2
Diazepam	1
Methadone	1
Sepsis	
Infarcted bowel and volvulus	3
Meningitis	1
Hypovolaemia	
Perforated aorta	1
Postrectal biopsy	1
Choanal atresia	1
Hypoglycaemia	1

*VSD=ventricular septal defect, PDA=patent ductus arteriosus.

Table 3 Drugs used in resuscitation

Drugs	No of arrests
Full cardiorespiratory arrests	26
No drugs	3
Adrenaline	22
With glucose	1
With atropine	17
With calcium	14
With sodium bicarbonate	19
Drugs used in pure respiratory arrests	21
None	7
Sodium bicarbonate	5
Naloxone	2
Aminophylline	2
Adrenaline	1
Atropine	1
Frusemide	1
Diazepam	1

tubated by paramedical staff. Though performed successfully, difficulties with intubation were expressed on six occasions. Various causes were given including the presence of vomitus in the trachea, laryngospasm, upper airway oedema and laryngeal distortion, and insufficient muscle paralysis.

Direct current shock was used during four paediatric cardiopulmonary resuscitation attempts, but was initially successful only once, and that child subsequently died. In each case direct current shock was used as a last attempted treatment in resistant asystole in the hope that the rhythm was an undiagnosed fine ventricular fibrillation.

Drug treatment was given in 23 of the 26 resuscitation attempts where cardiopulmonary arrest occurred. Adrenaline was administered in 22 or these cases either alone or in addition to atropine (17 cases), sodium bicarbonate (19 cases), or calcium (14 cases). The use of calcium is controversial; used injudiciously it can cause asystole. It should only be used in proved hypocalcaemia, hyperkalaemia or hypermagnesaemia, and in cases of massive blood transfusion. It was widely used in our study but always towards the end of cardiopulmonary resuscitation attempts when other therapeutic interventions had failed. Table 3 shows these drugs and also those used in respiratory arrest. Drugs were administered intravenously or down the endotracheal tube. In no case were drugs given by direct needling of the heart.

In nine of the 13 initially unsuccessful cardiopulmonary resuscitation attempts a consultant or senior registrar was involved in the decision to stop resuscitation.

OUTCOME

Thirty one (69%) of the 45 paediatric resuscitation attempts were initially successful. Only 49% of the children were alive one month after the arrest however, and 37% remained alive 12 months after the arrest. Two patients were lost to follow up. There was a marked contrast in outcome between arrests that were purely respiratory and those that were cardiopulmonary in origin. Thirty six per cent of children having a primary non-respiratory arrest survived initially, and 18% were alive after 12 months. Of patients having a pure respiratory arrest 82% survived initially and 44% were alive 12 months after the arrest (table 4). Of the two children who had more than one arrest, the boy (who had three arrests) is at home requiring continuous oxygen treatment; the girl died, aged 10 months, after it was agreed with her parents at the local hospital that no further resuscitative attempts should be made.

Table 4 Outcome of cardiopulmonary resuscitation attempts

Type of arrest	Initial death	Initial success	One month survival	One year survival
Underlying cardiac cause (n=11)	7	4	2	2
Full cardiopulmonary arrest (n=16)	7	9	6	4
Initial pure respiratory arrest (n=18)	0	18	11	10
Total (n=45)	14	31	19	16*

*Two lost to follow up.

Table 5 Duration of cardiopulmonary resuscitation attempts related to successful outcome

Length of resuscitation (minutes)	Initial deaths	Initial success	One month survival
0–5	0	11	9
5–10	0	7	4
10–15	1	4	3
15–30	4	7	3
30–60	8	2	0
>60	1	0	0
	13/45	31/45	19/41

Seven of the cardiopulmonary arrests occurred at home and all these children have subsequently died. Four had unsuccessful resuscitation. Of the other three children one died after three days, another after 11 days, and one after nine months. This last child had a history of perinatal asphyxia and a decision not to continue active resuscitative measures was taken.

Three children arrested in the accident and emergency department; of these two are alive and well 12 months after the event having had no neurological sequelae. The third child died from overwhelming sepsis.

Seventy per cent of successful resuscitation attempts were achieved within 15 minutes and 81% were within 30 minutes. There were no survivors one month after an arrest in which resuscitation was continued for more than 30 minutes (table 5). There was no case of hypothermia or near drowning who would have required prolonged cardiopulmonary resuscitation attempts.

None of the surviving 11 patients who was thought to be neurologically normal before cardiopulmonary arrest had any deficit in neurological or developmental attainment 12 months after the arrest. Sadly, one of these children has been the recipient of severe non-accidental injuries which may be related to difficulties in parental bonding during her stormy neonatal course.

There were no recorded preventable sequelae such as chest burns from defibrillation shocks or drip site fluid extravasations.

Discussion

CAUSES OF ARRESTS

The aetiology of cardiopulmonary arrest in children differs from that in adults.[1] In adults the event is often of cardiac origin. In children cardiopulmonary arrest may be the consequence

of profound hypoxaemia and acidosis caused by a variety of diseases leading to respiratory and eventually circulatory arrest. In this study 22 children had an arrest from a primarily respiratory disorder; five of these were prolonged apnoea attacks in neonates, four were postictal apnoea, and four were caused by infection. Acute obstruction was variously due to oedema from burns, a foreign body, laryngospasm, or bronchospasm and croup. Eleven were cardiac in origin, eight of which occurred in patients previously known to the cardiologists.

Two infants with critical aortic stenosis and a child with myocarditis presented to accident and emergency without a history of previous illness. Four children had drug induced arrests. Three of these were iatrogenic, two following postoperative morphine in very small infants and one after anticonvulsant treatment for prolonged seizures. Four were due to overwhelming infection. Two of the three children who were hypovolaemic had had relative simple surgical procedures. One child had hypoglycaemia (table 2).

Some of these arrests may have been anticipated and possibly prevented. For example, laryngeal oedema after a burn to the face and neck, opiate induced apnoea, and postoperative hypovolaemia.

In 33 children in whom a cardiac rhythm was noted, asystole was found in 17 and bradycardia in a further 12 cases. The findings of Eisenberg *et al* were similar. In their study 66% of childhood arrests were in asystole.[1] Ventricular fibrillation is an uncommon rhythm disturbance in paediatric cardiopulmonary resuscitation, and is found in 9% of paediatric cardiopulmonary arrests.[1] Our study substantiates this finding. Direct current shock was only used four times on the paediatric patients in our study. It was used in adrenaline induced ventricular fibrillation or in the hope that a refractory asystolic rhythm was a fine ventricular fibrillation.

RESPONSE AND MANAGEMENT BY CRASH TEAM

Audit of the team's response to arrests has led to several changes.

First, the need for training has been highlighted and lent weight to the application for a resuscitation training officer.

Cardiopulmonary arrest events occur rarely in children. The crash team was required to resuscitate on 46 occasions in the year of this study (less than once a week). There were less than two arrests each year on any one medical ward. Any individual member of the resuscitation team is likely to be called on to perform cardiopulmonary resuscitation on few occasions each year, and a nurse on a general paediatric ward even less often. In a district hospital which sees approximately 20000 children in the accident and emergency department a year and has no supraregional paediatric units, about five to 10 a year can be expected. Knowledge and skill in resuscitation deteriorates with disuse.[7-10] Regular in service training in resuscitation and refresher programmes are essential to establish and maintain a service of high standard. Training should include paediatric and adult practice as paediatric patients are visited by all ages of the public, and any large hospital is supported by a great number of staff. The necessary equipment should be available and familiar to all who may need to use it.

Second, this study showed a clear need for drug treatment protocols for use in common dysrhythmias in cardiopulmonary arrests. The algorithms devised by Advanced Paediatric Life Support (APLS UK) are now in use.[11] It also led to improvements in the audit form to record more accurately the order, timing, and doses of drugs used during an arrest.

Third, the resuscitation committee was an important focus for interspecialty discussion and implemented modifications to equipment and the contents of the drugs box.

OUTCOME

In our study there was an overall initial success rate after cardiopulmonary arrest of 70%, with 37% survival of 12 months. This compares favourably with previous studies from paediatric centres abroad. Erlich *et al* in Boston in 239 paediatric arrests over a six year period recorded an initial success response in 78%, with 47% discharged from intensive care in a satisfactory condition.[12] Wark and Overton in Sydney found a 66% initial success rate, with 42% leaving hospital.[13] Neither of these studies gives survival rates at 12 months.

Our results support previous experience that respiratory arrests occur more often than cardiac arrests in children and have a considerably better outcome.[1 12] Arrests from any cause occurring outside the hospital have a poor outcome, however.[14] This is despite the attendance of paramedical staff. In our study five of seven cases were intubated at the scene by paramedical staff. Also in our study there were no long term survivors from resuscitation attempts that were longer than 30 minutes. None of the children had hypothermia, was a case of near drowning, or a refractory drug induced arrest that would have warranted longer resuscitative measures.

It is encouraging that all surviving patients who were neurologically normal before the arrest remained so 12 months after the arrest. The follow up assessment of these children through casenote review and discussions with the family doctor may not have detected subtle neurological and developmental changes. It would be informative to make more detailed assessments at regular intervals after cardiopulmonary resuscitation.

Conclusions

Audit of cardiopulmonary resuscitation in a paediatric hospital has provided useful information about the standard of service given to our patients. This study has led to modifications to the equipment and drugs provided for resuscitation, emphasised the need for cardiopulmonary resuscitation training, and sought to improve the audit itself with better questionnaire forms. Regular audit is essential to determine whether such changes achieve the desired aims.

We thank all the members of the crash team at the Royal Liverpool Children's Hospital who participated in this study and the resuscitation committee for their helpful comments.

1 Eisenberg M, Bergner L, Hallstrom A. Epidemiology of cardiac arrests and resuscitation in children. *Ann Emerg Med* 1983; **12**: 672–4.
2 Thompson JE, Bonner B, Lower GM Jr. Pediatric cardiopulmonary arrest in rural populations. *Pediatrics* 1990; **86**: 302–6.
3 Stopfkuchen H, Stein G, Ouisse Luft A, *et al*. Results of cardiopulmonary resuscitation in children. *Klin Padiatr* 1989; **201**: 373–6.
4 Barzily Z, Somakh E, Sagy M, Boichis H. Pediatric cardiopulmonary resuscitation outcome. *J Med* 1988; **19**: 229–41.
5 Tunstall-Pedoe H, Bailey L, Chamberlain DA, Ward ME, Zideman DA. Survey of 3765 cardiopulmonary resuscitations in British hospitals (the BRESUS Study): methods and overall results. *BMJ* 1992; **304**: 1347–51.
6 Zideman DA. Resuscitation of infants and children. In: Evans TR, ed. *ABC of resuscitation*. London: BMJ Publications, 1990: 57–62.
7 Oakley PA. Inaccuracy and delay in decision making in paediatric resuscitation and a proposed reference chart to reduce errors. *BMJ* 1988; **297**: 817–9.
8 Skinner DV, Camm AJ, Miles S. Cardiopulmonary resuscitation skills of pre-registration house officers. *BMJ* 1985; **290**: 1549–50.
9 Marteau TM, Wynne G, Kaye W, Evans TR. Resuscitation experience without feedback increases confidence but not skill. *BMJ* 1990; **300**: 849–50.
10 Laxton AGP. Occasional paediatric resuscitation: misuse of equipment [Letter]. *Anaesthesia* 1989; **44**: 84.
11 Mackway-Jones K, Molyneux EM, Phillips B, eds. *APLS (UK) course manual*. ALS Courses Manchester and Liverpool Universities, 1992.
12 Erlich R, Emmett SM, Rodrigues Torres R. Pediatric cardiac resuscitation team: a six year study. *J Pediatr* 1974; **84**: 152–5.
13 Wark H, Overton JH. A paediatric 'cardiac arrest' survey. *Br J Anaesth* 1989; **56**: 1271–4.
14 Bray RJ. The management of cardiac arrest in infants and children. *Br J Hosp Med* 1985; **34**: 72–81.

Appendix Contents of emergency equipment boxes. Total number of boxes: 25 on wards, 16 in departments

Ambu bag and oxygen tubing
Three sizes of facemask: small, medium, and large
Set of Guedal Airways 000–4
Laryngoscope handle plus three blades: Mackintosh, straight, and baby
Endotracheal tubes cut to size 2·5–7·5 mm uncuffed, 8–9·5 cuffed
Set of uncut endotracheal tubes: 2·5–7·5 uncuffed, 8–9·5 cuffed*
Suction catheters sizes 5–12, two of each
Yankauer sucker
Plastic syringe (10 ml) for cuffed tubes
Plastic artery clip for cuffed tubes
Spare batteries and bulbs
Ayres T piece with Jackson Rees attachment*
Nasal oxygen cannulas
Length of tubing suitable for attachment to oxygen source
Large nasogastric tube

*Added since audit began.