ORIGINAL ARTICLE

Do resuscitation attempts in children who die, cause injury?

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Objective: To determine the incidence, type, and pattern of injury related to resuscitation attempts in children who die.
Design: Retrospective review of ambulance, hospital, and necropsy case records.
Method: All children who died aged 0–14 years between 1994 and 1996, and underwent a full necropsy at the Victorian Institute of Forensic Medicine (Melbourne, Australia) were identified. Children who were subject to recognised trauma before resuscitation or died because of a congenital abnormality were excluded. The records of all remaining children were reviewed. Children were grouped according to whether resuscitation was attempted or not.
Results: From a total of 346 children who died, 204 (58.6%) were identified as meeting the inclusion criteria. Resuscitation was performed in 153 (75%) children and was started before ambulance arrival in 123 (60.3%) children. Injuries were detected at necropsy in 65 (42.5%) of children who had resuscitation compared with six (11.7%) of children who had no resuscitation ($p<0.0001$) χ^2 test. All but two of these injuries were of a minor nature consisting principally of bruises or abrasions. Two significant injuries were identified both occurring as a result of readily identifiable resuscitation procedures. The likelihood of injury increased with the length of resuscitation. In children resuscitated for less than 60 minutes the incidence of injury was 27% compared with 62% for children resuscitated for longer ($p<0.0001$).
Conclusion: This study has shown that cardiopulmonary resuscitation commonly causes minor injuries such as superficial bruises and abrasions and the likelihood of such injury increases with the duration of the cardiopulmonary resuscitation. This information should reassure parents and caregivers that basic life support may be instituted without fear of causing significant injury or adversely affecting outcome in the child with cardiorespiratory arrest. Caution must be exercised when attributing significant injuries to resuscitation attempts and alternative causes must be fully investigated.

Cardiopulmonary resuscitation (CPR) is a widely promoted practice that is actively taught to the general public as well as medical, nursing, and paramedical personnel. It has been estimated that one in 40 Australians have received formal training in CPR[1] although it is unknown how often it is actually performed.

As CPR consists of a series of physical manoeuvres performed by one or more individuals upon another, the potential exists for injuries to occur to the recipient. A wide range of injuries have been described as being inflicted during CPR.[2–8] These range from superficial bruising through to chest or airway injury that is likely to impair the resuscitation attempt. The overall incidence of injury has been estimated at between 20%–65% in adults[4 6 7 9] and 7% in children.[10]

There are only four studies we could identify that specifically looked at CPR injuries in children. Two studies concentrated on rib fractures,[11 12] one on retinal haemorrhages,[13] while Bush *et al*[10] examined all injuries related to CPR. Feeldman *et al* compared radiographs of three cohorts of children. In the cohort of children receiving CPR they identified a single rib fracture in 50 children examined, and in this case abuse was not totally excluded. Spevak *et al* in a postmortem based study examined 91 children aged 1 year or less who underwent CPR. They found no rib fractures. Gilliand *et al* concentrated specifically on retinal haemorrhages. They found 70 cases of retinal haemorrhage in 169 paediatric necropsies. Major head injury was implicated in 69 of these cases. Bush *et al* examined all injuries attributable to CPR in a postmortem based study of 211 children. They reported a 7% incidence of any injury. Fifty per cent of these injuries were minor bruises and abrasions. They found seven cases (3%) of what they termed "serious" injury.

There are no previously published Australian studies on this topic. As it is probable that the incidence of CPR injuries is related to the method, training, and community awareness of the technique of performing CPR, there may be differences between geographical areas.[14]

Significant injury attributable to resuscitation procedures in children is probably uncommon: this is particularly true of retinal haemorrhages and rib fractures.[10 11 15–20]

Interpretation of injuries found after alleged or reported resuscitation procedures may be of forensic importance. Informed interpretation of such injuries is not possible without knowledge of injuries commonly produced by resuscitation.

The purpose of this study is to determine the incidence, type, and pattern of injury related to resuscitation attempts in children who die.

METHOD

All children aged 0–14 years who died in the period 1994 to 1996, and underwent a full necropsy at the Victorian Institute of Forensic Medicine (Melbourne, Australia) were identified via an electronic data search of the Institute's records.

All necropsies were conducted according to the national SIDS necropsy protocol. Children who were subject to recognised trauma before resuscitation, or died because of a congenital abnormality were excluded. Cases involving isolated minor trauma such as neck or facial compression were included only where additional trauma could be reasonably excluded on history and postmortem examination. For

Table 1 Cause of death of included children

Cause	Number of cases (n=204)
Sudden infant death syndrome	132
Drowning	18
Pneumonia	12
Sepsis	6
Asphyxia	8
Undetermined	3
Other	25

the purposes of this study, an isolated cardiac lesion was not regarded as a major congenital abnormality.

Cases in which necropsy or clinical data were unavailable were also excluded. The records of all remaining children were reviewed.

Ethics committee approval was obtained from the relevant ethics and research committees before data collection from the Victorian Institute of Forensic Medicine, the Royal Children's Hospital, and the Monash Medical Centre.

Explicit data were extracted from the case histories using a formatted data collection sheet. Details collected included patient demographics, persons present, resuscitation providers, resuscitation procedures, and duration and injury detected at necropsy. The principal investigator reviewed all records.

The recording of any attempt at expired air respiration or chest compressions was accepted as being an attempt at CPR. Children were grouped according to whether resuscitation was attempted or not.

Initially, attempts were made to identify the people who provided the CPR and their skill level. This proved impossible to determine accurately and in many cases several people with different skill levels performed CPR on the same child. It was therefore not possible in this study to correlate injuries with either the number or skill level of the resuscitation provider.

RESULTS

Of the 346 children who died during the study period, 142 (41.4%) were excluded from further analysis. The remaining 204 (58.6%) met all inclusion criteria.

The median age of the group was 4 months (1 day to 14 years). Some 117 (57.3%) were male. The cause of death as determined by the pathologist is shown in table 1. The most common cause of death was sudden infant death syndrome.

Cardiac arrest occurred in the home in 174 (85.3%) cases.

Resuscitation was performed in 153 (75%) children and was started before ambulance arrival by parents or other bystanders in 123 (60.3%) children. Ambulance personnel started CPR in a further 21 instances and medical staff in nine instances. Parental or bystander CPR was therefore started in 60.7% of the entire group or 80.3 % of the resuscitated group. Of the parents/bystanders who provided resuscitation, only a minority were recorded as being trained in basic life support. Many of the parents who started resuscitation did so under the instruction of the ambulance service via telephone.

Injuries were detected in 65 (42.5%) children in the resuscitated group compared with six (11.7 %) children in the non-resuscitated group. This difference is highly significant ($p<0.0001$). A full list of injuries detected in both groups appears in table 2.

Injuries in the resuscitated group

In the resuscitated group multiple injuries were detected in 31 children and two children were judged to have sustained significant injuries, that is, injuries with the potential to adversely effect the resuscitation. The first was an avulsed incisor tooth. This occurred in a child with muscular dystrophy. Intubation was difficult and a surgical airway was created after failure of orotracheal intubation. The second case was a large haematoma complicating an interosseous infusion. There was no injury in any child, which was judged to be life threatening or contributory to death.

Most injuries detected in this group were cutaneous bruises or abrasions 84 (68.8%). Of these 31 (36.9 %) involved the scalp and face, 15 (17.8%) involved the anterior chest, and 21 (25%) were related to intravascular access devices.

Injuries to the airway accounted for 18 (11.9%) of the injuries seen in this group. Nine of these injuries consisted of minor injury to the nasal mucosa resulting in epistaxis. There were several cases of mucosal ulceration, oedema, and minor haemorrhage involving the larynx. There was no case of disruption of the trachea and bronchi and no case of unrecognised oesophageal intubation.

Macroscopic pulmonary contusion was detected in seven children accounting for 4% of the injuries detected. All of these contusions were small in volume representing at most, fractions of a lobe. None of these injuries were judged by the pathologist to be contributory to death.

There were no rib fractures nor major visceral injuries detected.

Injuries in the non-resuscitated group

In the non-resuscitated group there were seven injuries detected in six cases with one child having two injuries. There were three abrasions, two bruises, and two small lip lacerations. None of these injuries were thought to be significant.

Duration of resuscitation and presence of injury

The median duration of resuscitation was 35.6 (1–540) minutes.

There was a correlation between duration of resuscitation and incidence of injury. In children resuscitated for less than

Table 2 Summary of injuries detected

Injury type	Resuscitated group	Non-resuscitated group
Incidence of injury	65/153	6/51
Incidence of multiple injury	31	1
Superficial bruises/abrasions	63	5
Intravascular access device bruises	23	
Airway injury	18	
Lip injury	9	2
Pulmonary contusion	7	
Splenic haematoma	1	
Dental injury	1	
Total injuries	122 in 65 cases	7 in 6 cases

60 minutes the incidence of injury was 27% compared with 62% for children resuscitated for periods greater than 60 minutes ($p<0.0001$).

DISCUSSION

The findings of this study indicate that resuscitation attempts in children who ultimately die do cause injuries and the number of injuries increases with the duration of the CPR. The majority of these injuries however are of a minor nature and would not by their nature be expected to hamper the resuscitation efforts. Indeed injuries such as bruising or abrasions to the face and chest may be reasonably anticipated by the physical nature of CPR being applied under stressful circumstances.

The absence of injuries that may have interfered with resuscitation attempts, indicates that instituting basic life support in a child with cardiorespiratory arrest is a safe practice even when the resuscitation provider may be inexperienced or untrained. This study does not provide information as to whether CPR is effective when provided by an inexperienced or untrained person merely that they do not cause serious injury when doing so.

Many case reports exist describing unusual and severe injuries after resuscitation of children.[21–24] These include injuries such as cardiac rupture,[22] hepatic laceration,[23] and gastric perforation.[21] In the absence of a more plausible explanation these injuries are often attributed to the resuscitation efforts. As this study suggests that such injuries are extremely rare it is possible that some of the injuries described in these case reports may represent trauma occurring before, and contributing to, the child's cardiorespiratory arrest.

The absence of serious injuries in this study suggests caution should be exercised when attributing serious injuries to CPR. Alternative causes for the injury should be vigorously investigated. Hitherto unrecognised trauma causing the death of a child is clearly of enormous forensic significance and should raise the possibility of a non-accidental injury.

Sirbaugh *et al*,[25] in a recent population based study of paediatric out of hospital arrest found that although a majority of paediatric arrests in Houston, Texas, occurred in the home, with the family present, resuscitative efforts were only instituted in a minority of cases (17%). This compares with a rate of 60.7% in this study and indicates either a greater familiarity with and acceptance of resuscitation practices in Australia or a more aggressive policy of encouraging CPR by the ambulance service once an emergency call has been made.

It is important to note the study group is comprised solely of children who underwent unsuccessful resuscitation. Injuries produced in the absence of spontaneous circulation may differ from the situation where circulation is restored. For example, injuries such as bruising or airway swelling may become apparent or more pronounced upon restoration of a circulation. This limits the external validity of the study and the findings may not be accurately extrapolated to successfully resuscitated children.

In conclusion, this study has shown that CPR commonly causes minor injuries such as superficial bruises and abrasions and the likelihood of such injury increases with the duration of the CPR. This information should reassure parents and caregivers that basic life support may be instituted without fear of causing significant injury or adversely affecting outcome in the child with cardiorespiratory arrest.

Caution must be exercised when attributing significant injuries to resuscitation attempts and alternative causes must be fully investigated.

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Contributors

D Wells initiated the study formulating the initial study design. The core ideas were discussed with M Ryan and S Young. M Ryan constructed the dataset to be collected and modifications were suggested by D Wells. M Ryan was responsible for the literature search with help from D Wells and S Young. M Ryan was responsible for data collection, tabulation, and analysis. Margaret Henry performed the statistical analysis. S Young and D Wells interpreted the data and edited the paper. M Ryan will act as guarantor for this paper.

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