

Rib fractures and cardiopulmonary resuscitation in small children

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ABSTRACT Background: Cardiopulmonary resuscitation (CPR) is sometimes claimed to have caused rib or sternal fractures in child abuse cases. It is both medically and legally important to establish whether rib fractures are secondary to abuse or a result of CPR. Such fractures are significant when identified, and in small children considered pathognomonic for child abuse. It was therefore decided to go through our archives to investigate rib fractures in small children. Method: A large forensic material from Western Norway was investigated retrospectively. All fractures were registered in autopsied small children below 5 years of age. All information of cardiopulmonary resuscitation in these small children was also registered. Results: Among 9632 forensic post mortem examinations performed from 1985 through 2004, 261 examinations were performed on children below 5 years of age. Among these 261, CPR was performed in 142. Only six had rib fractures, three homicides and three accidents. All fractures were either posterior or lateral, with the exception of one child with osteogenesis imperfecta who was involved in a car accident and had two anterior rib fractures. All the children had an injury pattern and an injury history that could explain both the rib fractures and their death. Most fractures were discovered by x-ray examination before autopsy and some during the autopsy procedure. Conclusion: Radiology performed before autopsy should be a routine part of every infant autopsy to reveal both recent and old fractures, both in ribs and in other parts of the skeleton. Some recent fractures will only be found at autopsy, while some old fractures may be overlooked at autopsy if the pleural membrane is not reflected. The findings support previous studies in that CPR is not a common cause of rib fractures, and that it does not lead to posterior fractures.

Key words Rib fracture, cardiopulmonary resuscitation (CPR), child abuse

INTRODUCTION

Although rib fractures themselves are not necessarily life threatening, they are significant when identified, and in small children considered pathognomonic for child abuse. Most rib fractures in infants are caused by child abuse and make up between 5% and 27% of all skeletal injuries in abused children (1,2). Rib fractures may not be evident on radiographs in the acute stage, as little displacement occurs. Several studies have shown that rib fractures seldom are accompanied by external evidence of trauma (2,3,4). They are often not identified until in the healing stage, as a result of developed callus, and are often found coincidentally if there are not other injuries.

Cardiopulmonary resuscitation (CPR) is sometimes claimed to have caused rib or sternal fractures in child abuse cases. It is both medically and legally important to establish whether rib fractures are secondary to abuse or a result of CPR. It is also important to rule out the possibility that a fracture might have rare causes such as bone dysplasia or prematurity.

The objective of this study was to

identify rib fractures in infants and small children in a large forensic material, with particular focus on rib fractures caused by cardiopulmonary resuscitation.

MATERIAL AND METHODS

The study is retrospective. The material was collected from medico-legal reports, based upon forensic examinations performed at the forensic unit in a 20-year period from the 1985 throughout 2004. There were performed 9632 forensic post mortem examinations during this period. From the police reports in each case, medical and other data were available. All post mortem examined infants and small children aged from 0 throughout 4 years were reviewed, and a number of demographic factors registered. Children dying on the same day as they were born, were registered with an age of 0 days. In all cases where child abuse was suspected, whole body x-ray examinations were performed. A number of projections were performed to give the best result in every case. These radiographs were all examined in the Department of Paediatric Radiology and reviewed by one or two experienced paediatric radiologists prior to autopsy. In a few cases, specimen radiography was performed in the autopsy room, using a radiation-shielded cabinet (Faxitron X-ray systems, model 43804N, Hewlett Packard), in combination with ready-made film in envelopes (Kodak X-Omat MA, Ready Pack), giving an excellent quality. In some cases with very small children, this equipment

was used in whole body radiography. These radiographs were reviewed by the forensic pathologists before or during the autopsy. In about half of the cases originally suspected to be SIDS cases, or undetermined manner of death, x-ray examinations were performed, but not systematically. These cases were examined using a stationary x-ray instrument in the autopsy room, where only one frontal projection was made. The radiographs were reviewed by the forensic pathologist before the autopsy and by a radiologist later. These radiographs were of lesser quality than the x-rays taken in the Department of Radiology. None of the x-rays were reviewed during the study, just the reports. Inspection and manual examination of the chest wall during the autopsy procedure were performed in all cases. All injuries, including fractures were registered. Data extracted from the individual patient charts included: age, sex, number and location of rib fractures and associated injuries. If CPR was performed, it was registered who had performed the resuscitation attempt.

The Regional Committee for Medical Research Ethics in Western Norway has approved the study.

RESULTS

Among the 9632 medicolegal examinations in the 20-year period, there were 261 (2.7%) medico-legal examinations of children below 5 years of age where a full autopsy was performed. Of these 261 cases, 158 (60.5%) were boys and

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103 (39.5%) girls. The age distribution range was from 0 years to 4 years and 11 months (mean 297.4 days, median 144.5 days). There were 31 (11.9%) victims of accidents, 12 (4.6%) homicide victims, 43 (16.5%) cases of natural death, and 175 (67.0%) children with an unknown manner of death, all certified as cases of SIDS (Table 1). Of the 261 cases, CPR was performed in 142 cases. Health care workers performed CPR in 119 cases, parents or other unskilled personnel in 23 cases. In 68 cases, no information indicated whether CPR had been performed or not, and in 51 cases no CPR had been performed. It was not possible to find reliable information of the length of the individual resuscitation period.

Rib fractures were discovered in 6 of the 261 cases (Table 1). In 3 of these cases, health care workers had performed CPR. In the other 3, CPR was not performed (Table 2). Sternal fractures were not found. The rib fractures were found in 3 victims of high-energy traumatic accidents and 3 victims of homicides. Five of the six children had posterior rib fractures. The sixth had two right anterior rib fractures discovered during the post mortem examination, but not seen on x-ray examination. No CPR was performed on this sixth child suffering from osteogenesis imperfecta (OI). The child was involved in a car accident. The original four-point safety belt had been replaced with a weaker, non-original, type. The

belt snapped on the right side, and the child was thrown around in the car. The sites of the fractures were consistent with the pressure from the right safety-belt.

DISCUSSION

Children are less vulnerable to rib fractures than adults because of the plasticity of the rib cage. The anterior parts of the ribs consist of cartilage. Ossification first begins toward the end of the second month of foetal life, and is a process, which develops gradually. Rib fractures are much more common in older people than in young adults.

Rib fractures-mechanism

Rib fractures occur by anterior-posterior compression or a direct trauma (1,5,6,7). Anterior-posterior compression will stress the lateral aspects of the ribs and can result in lateral rib fractures.

In addition to compression, direct trauma of sufficient force to the thorax can result in rib fractures at the site of impact. Both of these fracture mechanisms require substantial force (8).

In infants with unexplained fractures, causes of bone fragility such as osteogenesis imperfecta (OI), rickets/ vit-D deficiency and osteopenia/ prematurity (in very low birth weight infants) must be considered. OI, the most common genetic cause of bone fragility, is a heterogeneous disorder caused by a molecular defect of collagen (9,10). A case

has been reported where chest compressions were performed in an infant with OI type 2, without any new rib fractures (11). This supports previous reports that have concluded that rib fractures rarely, if ever result from CPR in children, even in children with a lethal bone disease. Rib fractures which occur secondary to birth trauma are often located posteriorly near the costovertebral junction. In rare cases, severe coughing has been reported as a cause of rib fractures (12). Rib fractures have also been seen after chest physiotherapy in infants. These have been found to be lateral and posterior fractures (12).

In a animal study it has been shown by simultaneous CT imaging, that squeezing the chest with the fingers, leads to levering of the ribs over the transverse processes of the spine, leading to rib fractures, all posterior (5). If a small, unsupported baby is resuscitated with the hands encircling the chest, there is accordingly a risk of posterior rib fractures (6). This so called two-thumb CPR chest compression method resembles the abusive compression or shaking of an infant (13). Many of the cited studies in the literature were published before the International Consensus on Science's revised guidelines in 2000 (14). It is thus important to detail the resuscitation techniques used. In the animal study, when CPR was performed on a firm surface, this movement could not occur, and posterior rib fractures were not found (5). It is therefore argued that posterior fractures in a child who has been resuscitated on a firm surface would be inconsistent with the biomechanics of resuscitation (5,15). Establishing the mechanisms of trauma from the injuries has recently been reviewed (6).

CPR and rib fractures

In many cases of the present study, it was difficult to get information of whether CPR was performed or not. In a substantial number of cases there were no information about CPR, a well-known procedure in Norway already in the eighties. Information was regularly missing in cases from the period 1985-90, which was the peak period of the SIDS "epidemic" in Norway, when a high number of SIDS cases were examined annually. CPR was performed on many of these, but documentation is lacking. Therefore the group "No CPR information" in Table 2, probably could be substantially reduced, theoretically making the incidence of fractures even lower.

There was no difference as to who had performed the CPR in the present study. It is sometimes believed that parents or non-medical personnel can cause injuries

Table 1. Rib fractures

Fractures	Natural death		Accident		Homicide		Unknown		Total	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Present	0	0	2	1	1	2	0	0	3	3
Not present	27	16	14	14	6	3	108	67	155	100
Total	27	16	16	15	7	5	108	67	158	103
	43		31		12		175		261	

Table 1. The number of victims with rib fractures according to the manner of death is shown.

Table 2. CPR

CPR	Fractures present		Fractures not present		Total	
	Male	Female	Male	Female	Male	Female
CPR - Medical	1	2	75	41	76	43
CPR - Other	0	0	14	9	14	9
No CPR performed	1	1	29	20	30	21
No CPR information	1	0	37	30	38	30
Total	3	3	155	100	158	103
	6		255		261	

Table 2. CPR and the number of victims with and without rib fractures is shown. In a number of cases no CPR was performed, and in a large number of cases, no information was present.

by performing CPR in a wrong manner. It is, however, established in studies of CPR performed by adults, that non medical personnel is more afraid of using force than professionals are, and rarely cause injuries. In one review where CPR performance of non-medical and medical personnel was compared, no difference in the frequency of rib fractures as adverse effects was found (16). This review included only adults, but probably also applies to children. Unfortunately, we had no systematic information of how long and how intense the CPR procedures were. It is, however, discussed whether this is of importance or not (17).

Rib fracture identification

Sometimes rib fractures can be overlooked by radiography. This was the case in one of the accident cases, where x-rays were performed as a part of the routine in the emergency room. In the suspected abuse cases where a paediatric radiologist had performed and reviewed the x-rays, all rib fractures were found and confirmed by autopsy. In the present study, inspection and a gentle manual examination of the chest wall were performed. The parietal pleura was, however, not routinely removed. The authors feel, however, convinced that no recent fractures were overlooked. Old fractures, however, may have been overlooked if the callus only was of modest size. In several studies, post-mortem skeletal surveys were included (18,19,20,21,22). In some studies, the ribs were dissected and the pleural membrane reflected back in infants and very young children, to find rib fractures (15,22). This method is probably the method of choice and will lead to finding of all fractures, both recent and old. None of the studies above referred to the use of specimen radiography, which has been proposed as the optimal method of detecting subtle fractures at postmortem examination (23). In our study, specimen radiography was performed in many cases, in a Faxitron x-ray cabinet, with excellent quality of the radiographs. This was, however, not done routinely.

Rib fracture causes

Among the 31 victims of accidents (mean age 2.8 years) in our material only three had rib fractures. All information from the accidents, together with medical information indicated that these rib fractures were caused by high-energy traumas (Table 3). Among the 28 remaining children, 8 were also involved in accidents classified as high-energy traumas, without any signs of rib fractures, indicating that substantial force is necessary for a fracture to occur. Among the 12 homicide victims, three had posterior rib

fractures. Two of these were abuse cases while one was a homicide on a newborn, by a young girl having secretly giving birth to the child. In the abuse cases, available information revealed that both shaking and squeezing had taken place, indicating that this caused the fractures, and not CPR.

Although most previous reviews have shown that most rib fractures in infants are caused by child abuse, some studies have revealed that fractures of ventral parts of the thorax can occur during resuscitation. In a recent systematic review of studies addressing rib fractures and CPR in children, 6 studies were included where 923 children underwent CPR (24). Three children had rib fractures attributed to CPR. Reports on conventional CPR in adults suggest an incidence of rib fractures ranging from 13% to 97%, and of sternal fractures from 1 to 43% (17). Rib fractures after cardiopulmonary resuscitation in children are rare. When they do occur, they are either mid-clavicular or at the sternochondral junction (24). The locations of these fractures are in contrast to the posterior rib fractures, which are more commonly found as a result of abuse in infants and young children (1,3,18,25,26). Fractures resulting from abuse can also occur anteriorly (3,25).

Posterior rib fractures have not been described after CPR, except in a recent case where one posterior fracture was found and claimed to be caused by CPR (27).

SUMMARY

The findings in this study support previous studies in that CPR is not a common cause of rib fractures, and that it does not lead to posterior rib fractures. Rib fractures in children are significant when identified, and in small children considered pathognomonic for child abuse. Whole body radiology taken prior to autopsy should be a routine part of every infant autopsy, and reflection of the pleural membrane should be performed during the autopsy, as some rib fractures otherwise can be overlooked.

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