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Does cardiopulmonary resuscitation cause rib fractures in children? A systematic review☆

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Abstract

Background: There is a diagnostic dilemma when a child presents with rib fractures after cardiopulmonary resuscitation (CPR) where child abuse is suspected as the cause of collapse. We have performed a systematic review to establish the evidence base for the following questions: (i) Does cardiopulmonary resuscitation cause rib fractures in children? (ii) If so, what are the frequency and characteristics of these fractures that may help to distinguish them from rib fractures caused by physical abuse?

Methods: We performed a literature search of original articles, references, textbooks, and conference abstracts, published in any language from 1950 to 1 October 2005. Articles were identified from ASSIA, Caredata, Medline, Ovid Medline in Process, ChildData, CINAHL, Embase, ISI Proceedings, SIGLE, Science Citation Index, Social Science Citation Index, and TRIP databases. We included all studies that addressed rib fractures and CPR in children less than 18 years, and excluded review articles, expert opinion, consensus guidelines, and studies that were significantly methodologically flawed on critical appraisal. Each study underwent two independent reviews (with a third review if there was disagreement). Each reviewer used standardized criteria for study definition, data extraction, and critical appraisal, to determine the quality of the study and to establish if it met the inclusion criteria of this systematic review.

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Findings: Of the 427 studies reviewed, 6 were included: 1 case control, 4 cross-sectional, and 1 case series. These represent data on 923 children who underwent CPR. Three children sustained rib fractures as a result of resuscitation; all three of these had fractures that were anterior (two mid-clavicular and one costo-chondral). We did not find any child in the literature who had a posterior rib fracture due to CPR. Resuscitation was performed variably by both medical and non-medical personnel.
Conclusion: Rib fractures after cardiopulmonary resuscitation are rare. When they do occur, they are anterior and may be multiple. As the studies performed to date did not use the most sensitive techniques for detecting rib fractures, further prospective studies of children would be valuable to provide additional clarification on this question.

Keywords: Cardiopulmonary resuscitation; Rib fractures; Children

Background

Fractured ribs in children less than 3 years old have a high specificity for child abuse (Barsness et al., 2003; Bulloch et al., 2000; Cadzow & Armstrong, 2000; Garcia, Gotschall, Eichelberger, & Bowman, 1990; Leventhal, Thomas, Rosenfield, & Markowitz, 1993; McClelland & Heiple, 1982; Schweich & Fleisher, 1985; Strouse & Owings, 1995; Thomas, 1977). One study gives a positive predictive value of 95% that a rib fracture in children less than 3 years of age is an indicator of abuse (Barsness et al., 2003). The finding of rib fractures in a young child without underlying bone disease or a history of major trauma thus points strongly to a diagnosis of physical abuse.

Rib fractures are a recognised complication of cardiopulmonary resuscitation (CPR) in adults (Powner, Holcombe, & Mello, 1984). The thorax of an infant or young child is less rigid and has a higher degree of plasticity than that of an adult due to a higher proportion of cartilage, and it has therefore been postulated that a young child's chest can tolerate greater deformity before fracturing (Kleinman & Schlesinger, 1997). When a baby or young child is noted to have rib fractures following collapse from an unknown cause and subsequent CPR, the question arises as to whether the rib fractures were caused by abuse or by the resuscitation. This situation amounts to a challenging diagnostic dilemma, as was highlighted in a recent high-profile criminal case in the UK (Patel, 2003). It is important that paediatricians derive their opinion from an evidence base, and that when they are acting as expert medical witnesses in court, they are able to produce scientific evidence to justify their opinion. The evidence base in child protection, however, is ill-defined, and there are no systematic reviews published in the literature addressing this particular subject.

Objectives

The purpose of this study was thus to conduct a systematic review to address the following questions: (i) Does cardiopulmonary resuscitation cause rib fractures in children? (ii) If so, what are the frequency and characteristics of these fractures, and can they be differentiated from rib fractures arising from physical child abuse?

Methods

Criteria for considering studies for this review

The inclusion criteria were studies of children aged up to 18 years:

- with no underlying bone disease;
- who had external closed cardiac massage (CPR);
- where the occurrence of associated rib fractures was recorded.

We excluded review articles, expert opinion, consensus guidelines, and studies that were significantly methodologically flawed on critical appraisal. We also excluded studies with mixed adult and child subjects where the paediatric data could not be separated.

Search strategy

We conducted a literature search of original articles, references, textbooks, and conference abstracts, published in any language from 1950 to October 1, 2005, using the databases listed in Table 1 and 22 keywords relating to rib fractures and resuscitation (singly and in combination). We scanned all articles to identify primary studies that potentially met the inclusion criteria, which then underwent two formal reviews (see Fig. 1).

Methods of review

Each of the 427 studies that we identified had two independent reviews by a panel of 27 reviewers, drawn from paediatricians, paediatric radiologists and paediatric orthopaedic surgeons. To determine if the study was of the correct design and that the methodology was sound enough for inclusion, we used standardised critical appraisal and data extraction forms based on defined criteria by the NHS Centre for Reviews and Dissemination (NHS Centre for Reviews and Dissemination. Undertaking Systematic Reviews of Research on Effectiveness, 2001). In the event of disagreement between the original reviewers as to the study type (whether case series or cross-sectional, for example), or as to whether the study merited inclusion, a third review was conducted. Studies were evaluated with respect to the study type, the degree to which authors had excluded pre-existing abusive rib fractures or medical conditions predisposing to bone fragility prior to resuscitation, and the diagnostic investigations which were used to identify rib fractures.

Results

Description of studies

At the end of the review process, six studies met the inclusion criteria and had satisfactorily excluded important confounders, such as pre-existing bone disease, as listed above (Betz & Liebhardt, 1994; Bush, Jones, Cohle, & Johnson, 1996; Feldman & Brewer, 1984; Price, Rush, Perper, & Bell, 2000; Ryan, Young, & Wells, 2003; Spevak, Kleinman, Belanger, Primack, & Richmond, 1994). These studies, which are summarised in Table 2, represent data on a total of 923 children aged 0–14 years.

Table 1
Databases searched

Database and search period	Description
ASSIA (1987–2005)	The Applied Social Sciences Index and Abstracts on the Web is an indexing and abstracting tool covering health, social services, economics, politics, race relations, and education
Caredata (1980–2005)	Caredata is a social work and social care knowledge base
ChildData (1958–2005)	The National Children's Bureau database, ChildData, provides access to the NCB Library's four databases, covering policy, legislation, practice, and research, from current thinking to background/historical information, together with information on national and international childcare organisations, press coverage of issues affecting children and young people, and details of all the major childcare conferences and events. Updated monthly/quarterly
CINAHL (1982–2005)	The Cumulative Index to Nursing and Allied Health database provides authoritative coverage of the literature related to nursing and allied health
Embase (1980–2005)	The Excerpta Medica Database family consists of the main Embase database and its two subsets: embase drugs and pharmacology, and embase psychiatry
ISI Proceedings (1990–2005)	The Institute of Scientific Information Proceedings database contains over 2.5 million records from more than 60,000 conferences
Medline (1950–2005)	Ovid Medline® covers biomedicine and allied health, biological and physical sciences, humanities, and information science, as they relate to medicine and health care, communication disorders, and population and reproductive biology
Medline In-Process (2005)	The Ovid Medline® In-Process and Other Non-Indexed Citations (PREM), the National Library of Medicine's (NLM) in-process database for Ovid Medline, provides basic information and abstracts before a record is indexed with MeSH® heading(s) and added to Ovid Medline
Web of knowledge Science Citation Index Expanded (1981–2005) Social Science Citation Index (1981–2005)	These databases provide information on journal literature in the fields of behavioural, social, natural, physical and biomedical sciences and technology
SIGLE (1980–2005)	SIGLE is the System for Information on Grey Literature in Europe
TRIP (1997–2005)	The Turning Research into Practice database searches over 55 sites of high-quality medical information, providing direct, hyperlinked access to the largest collection of 'evidence-based' material on the web, as well as articles from leading online journals

Methodological quality

The included studies attempted to identify whether rib fractures are caused by CPR. The authors were careful to give the cause of cardiorespiratory collapse, and five out of six excluded prior abuse. The studies had a high degree of heterogeneity. They were retrospective and based on data extracted from medical case reports, radiographic findings, and autopsy reports. Studies incorporated different combinations of investigations, which varied according to the autopsy and radiology protocols adopted. Given the likely

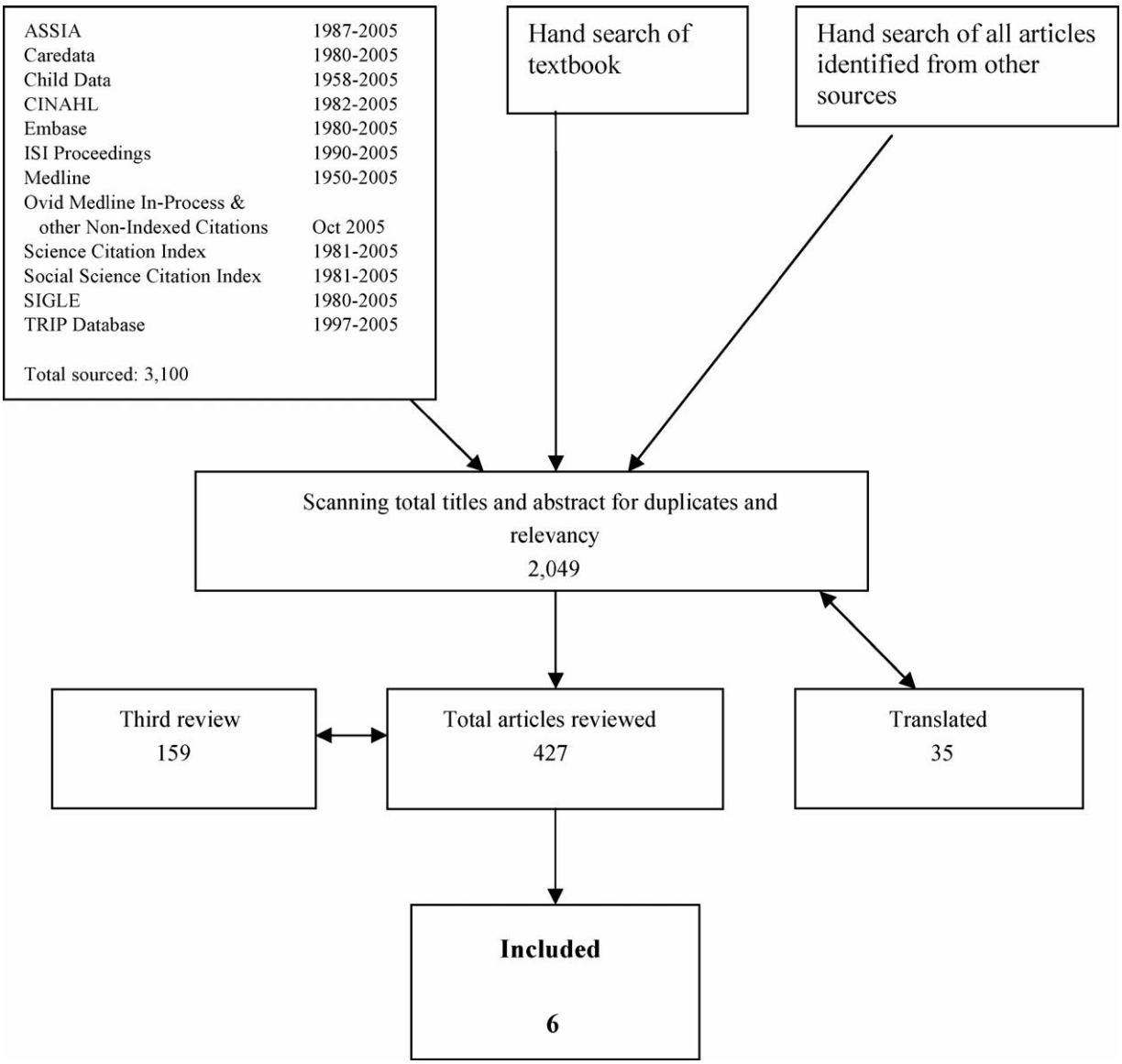

Fig. 1. Search strategy.

rarity of this complication, the studies included small numbers of cases (range 50–324). The age range of children included varied considerably between studies. The length of time of resuscitation was noted in four studies and ranged from 1 to 540 min (Bush et al., 1996; Ryan et al., 2003; Sewell & Steinberg, 2000; Spevak et al., 1994). Each study addressed external cardiac massage, but details of the technique were not described. Children were resuscitated by medical personnel, bystanders or a combination of both.

Table 2
Summary of included studies

Author, year and country	Ascertainment and investigations	Aims and study design	Inclusion criteria	Number of children with rib fractures/total number of children studied	Age range	Details of children with fractures	Duration of CPR for group
Feldman and Brewer (1984), USA	Medical records; chest radiograph	To ascertain the frequency of rib fractures after CPR and in abuse: case series	Non-traumatic deaths	0/50	0 –97 months	0	<90 min
Spevak et al. (1994), USA	Medical reports; skeletal survey; autopsy report including careful gross and occasional histological examination of ribs	To determine the incidence of rib fractures after CPR: cross-sectional	All causes of death except child abuse	0/91	0–8 .5 months	0	10–120 min
Betz and Liebhardt (1994), Germany	Autopsy reports (no detail given)	To document rib fractures caused by external CPR: cross-sectional	Non-traumatic deaths (CHD, SIDS, drowning, infection)	2/94(2.1%)	5 days to 7 years	Two-month-old with bilateral fractures of ribs II–V; 5-year-old with right-sided fractures of ribs II–VI. All fractures were mid-clavicular	Not stated
Bush et al. (1996), USA	Medical records; autopsy records	To assess type, rate, and severity of complications of CPR: cross-sectional	Non-traumatic deaths	1/211(0.47%)	6 h to 12 years	Three-month-old with bilateral sterno-chondral fractures of ribs VIII–IX	3–180 min

Table 2 (*Continued*)

Author, year and country	Ascertainment and investigations	Aims and study design	Inclusion criteria	Number of children with rib fractures/total number of children studied	Age range	Details of children with fractures	Duration of CPR for group
Price et al. (2000), USA	Medical records; autopsy reports; skeletal survey	To determine whether CPR causes fatal abdominal injuries; extra-abdominal injuries documented: case control study	Children who died of natural causes	0/324	0–10 years (246 < 1 year)	N/A	Not stated
Ryan et al. (2003), Australia	Autopsy according to Australian National SIDS Protocol	To determine incidence and pattern of injury related to CPR: cross-sectional	Non-traumatic deaths (congenital abnormalities excluded)	0/153	0–14 years	0	1–540 min

Data extracted from included studies

Out of a total of 923 documented cases of children undergoing CPR, there were only three children with rib fractures as a consequence; the frequency in individual studies ranged from 0 to 2% (Betz & Liebhardt, 1994; Bush et al., 1996). Significant differences in study design and the generally high degree of heterogeneity precluded a calculation of overall incidence. The fractures occurred in two babies aged 2 months and 3 months who died from sudden infant death, and a 5-year-old child who drowned. There was no suspicion of child abuse in any of these cases. Trained personnel resuscitated all three cases, while the 3-month-old was also resuscitated by untrained personnel for a total of 75 min; the duration of resuscitation was undefined in the other two cases. (Those children who did not develop rib fractures had been resuscitated for between 1 and 540 min.) The fractures found were all multiple and anterior: two of the three cases had mid-clavicular fractures (bilateral ribs II–V in one child, and on ribs II–VI on the right side of the other child) (Betz & Liebhardt, 1994), and one had bilateral fractures at the sternochondral junction of ribs VIII and IX. (Bush et al., 1996) (see Table 2 for further details). There were no posterior rib fractures due to CPR.

One study relied on radiography to identify rib fractures (Feldman & Brewer, 1984). The authors reviewed 50 children who underwent resuscitation and had subsequent chest X-rays. For 32 children, only early post-resuscitation films were available; the remaining children had follow-up films at 2 weeks. The authors reported one resuscitated child with a healing rib fracture due to previous abuse. There were no acute rib fractures in their CPR series.

Rib fractures were sought at postmortem in five of the studies (Betz & Liebhardt, 1994; Bush et al., 1996; Price et al., 2000; Ryan et al., 2003; Spevak et al., 1994). Postmortem skeletal surveys were included in all of Spevak's cases. Although Price et al. (2000) set out to identify abdominal injury as a complication of CPR, personal communication with the authors confirmed that the study also sought rib fractures. Each child in that study had postmortem skeletal surveys; in addition, the rib was dissected and the pleural membrane reflected back in infants and very young children, thereby significantly enhancing the prospects of finding any rib fractures. Ryan et al. (2003) all had standardised autopsies according to the Australian national SIDS autopsy protocol. No authors referred to the use of specimen radiography, which has been proposed as the optimal method of detecting subtle fractures at postmortem (Kleinman, Marks, Spevak, & Richmond, 1992).

Discussion

Individual studies within this review demonstrate that 98–100% of children who undergo cardiopulmonary resuscitation do not develop rib fractures as a consequence.

The retrospective nature, the small numbers of cases included to detect a rare complication, and the different methods used to identify rib fractures in the individual studies contribute to considerable heterogeneity, and are limitations to the final conclusions of the systematic review. The population of interest is children under 3 years, as rib fractures in this group have the highest positive predictive value for child abuse, but the majority of studies included a wider age range.

The differing methods of investigation used to identify children with rib fractures mean that the diagnostic sensitivity varied between studies. Rib fractures can be difficult to visualise radiologically (Kleinman, Marks, Adams, & Blackbourne, 1988), although detection may be improved by using oblique

films (Barsness et al., 2003; Ingram et al., 2000). Only one study included in this review examined survivors of resuscitation (Feldman & Brewer, 1984), and it was published prior to the recognition of this technique. Acute rib fractures are particularly difficult to visualise on standard antero-posterior (AP) chest radiographs, as were taken in this study.

Postmortem investigation varied between studies, and in no case was specimen radiography employed, which might have enhanced detection. Kleinman et al. have showed how postmortem specimen radiography has a 100% sensitivity and specificity for identifying rib fractures missed on standard AP chest radiographs or lateral imaging (Kleinman et al., 1992), and there is thus always the possibility that subtle fractures may have been missed in the included studies relying on postmortems with only standard AP radiography. It is also unclear within autopsy protocols whether the parietal pleura have been reflected off the ventral surface of the posterior ribs to ensure full visualisation in all cases. If this is not performed, a rib fracture is less likely to be detected, again raising the possibility of subtle fractures being missed in these studies.

When rib fractures occurred during resuscitation, they were either mid-clavicular or at the sternochondral junction. The location of these fractures is in contrast to the posterior rib fractures which are more commonly found as a result of abuse in infants and young children (Barsness et al., 2003; Betz & Liebhardt, 1994; Bulloch et al., 2000; Cadzow & Armstrong, 2000; Feldman & Brewer, 1984). It is worth noting, however, that rib fractures occurring in abuse can also occur anteriorly (Barsness et al., 2003; Cadzow & Armstrong, 2000). Gunther has described three cases of lateral and anterior rib fractures caused by abuse, where two of the children subsequently had CPR by trained and untrained personnel. The abusive injury was due to antero-posterior squeezing, leading to crushing fractures of the internal surface of the rib, without fracture of the external surface. In one fatal case, there were new fractures through old fractures, highlighting that the histological dating of fractures may be crucial to distinguish abusive from resuscitation-related fractures (Gunther, Symes, & Berryman, 2000). The relevance of dating any rib fractures was also shown by Klotzbach, Delling, Richter, Sperhake, and Puschel (2003) and Feldman and Brewer (1984).

Posterior rib fractures have not been described as a consequence of CPR. Indeed, the presence of posterior fractures in a child who has been resuscitated on a firm surface would appear inconsistent with the biomechanics of resuscitation (Kleinman & Schlesinger, 1997). Kleinman and Schlesinger's research combined laboratory studies and two case studies, and provides an eloquent explanation of the biomechanics of posterior rib fractures. Three dead rabbits had simulated CPR on a firm surface, with CT images throughout: no rib fractures were produced. The same rabbits were then lifted up, held with the fingers wrapped around the chest and the thumbs on the front of the chest, and squeezed until rib fractures were produced. These rib fractures were all posterior, and simultaneous CT imaging while the rabbits were being squeezed showed the ribs levering over the transverse processes of the spine. When CPR is performed with the child on a firm surface, this movement cannot occur, and posterior rib fractures cannot, therefore, result. Resuscitation of a newborn baby unsupported, with the hands encircling the chest, may, however, carry the theoretical risk of posterior rib fractures. It is thus important, when obtaining a history, to detail the resuscitation techniques used.

A number of studies were excluded on methodological grounds, although some important points arise in these studies. Sewell reported a newborn with osteogenesis imperfecta type II who had multiple fractures of varying ages of the ribs and all the extremities at birth (Sewell & Steinberg, 2000). Following delivery, the infant collapsed, and CPR was performed for 5 min. The infant survived for a further 2 days, and chest radiographs taken in this time did not demonstrate any new rib fractures following CPR. This paper was

excluded on the grounds of co-existing bone fragility, but is illustrative of the absence of rib fractures after CPR even in a vulnerable child. The implications of this case report are, however, limited by the early chest radiographs, where acute fractures may have been missed.

Severe injury as a consequence of vigorous CPR in adults is well described (Parke, 1993; Powner et al., 1984). Older publications, such as that by Thaler in 1962 (Thaler & Krause, 1962), have ascribed similar injuries to CPR in children. In one case of CPR, the 3-year-old child had a fractured XIth rib and a ruptured liver. Both of these injuries were attributed to resuscitation, but a significant traumatic or abusive event prior to her collapse was not adequately excluded. No explanation was given for the 3-year-old child suddenly becoming unconscious; clearly, a ruptured liver and subsequent exsanguination would have been an adequate cause. The child was also exposed to knee chest resuscitation, not consistent with modern CPR, as originally described by Kouwenhouven (Kouwenhouven, Jude, & Knickerbocker, 1960) and endorsed by the Paediatric Life Support (PALS) Working Group (Nadkarni et al., 1997). Due to the inadequate exclusion of physical abuse and atypical CPR technique in Thaler's study, we did not include it in our review.

Saternus et al. described high levels of iatrogenic complications of closed chest massage in two German cities, Cologne (23%) and Berlin (10%) (Saternus & Oehmichen, 1985). Of 89 infants resuscitated (age not given), seven had rib fractures, all anterior and multiple (between two and nine ribs fractured), four bilateral. All cases were resuscitated by medical personnel. No details of the cause of death were included, and there was no mention of excluding underlying bone disease or child abuse as a cause of death; this study was thus ineligible for inclusion.

In conclusion, the published evidence to date indicates that rib fractures are a rare complication of CPR in children, and that, when they do occur, they are likely to be anterior and may be multiple. No posterior rib fractures are recorded as a consequence of resuscitation, and there are sound biomechanical reasons for this. The findings of this review are limited by the weaknesses of the study designs and the varying degrees of rigour with which rib fractures were sought. Prospective studies of children undergoing CPR, using more sensitive radiological and autopsy methods to detect rib fractures, may offer a more definitive answer to this vital question.

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References

ASSIA (1987–2005).

Barsness, K. A., Cha, E. S., Bensard, D. D., Calkins, C. M., Partrick, D. A., Karrer, F. M., & Strain, J. D. (2003). The positive predictive value of rib fractures as an indicator of nonaccidental trauma in children. *Journal of Trauma: Injury, Infection and Critical Care*, *54*(6), 1107–1110.

Betz, P., & Liebhardt, E. (1994). Rib fractures in children—resuscitation or child abuse? *International Journal of Legal Medicine*, *106*(4), 215–218.

Bulloch, B., Schubert, C. J., Brophy, P. D., Johnson, N., Reed, M. H., & Shapiro, R. A. (2000). Cause and clinical characteristics of rib fractures in infants. *Pediatrics*, *105*(4), E48.

Bush, C. M., Jones, J. S., Cohle, S. D., & Johnson, H. (1996). Pediatric injuries from cardiopulmonary resuscitation. *Annals of Emergency Medicine*, *28*(1), 40–44.

Cadzow, S. P., & Armstrong, K. L. (2000). Rib fractures in infants: Red alert! The clinical features, investigations and child protection outcomes. *Journal of Paediatrics and Child Health*, *36*, 322–326.

Caredata (1980–2005).

ChildDate (1958–2005).

CINAHL (1982–2005).

Embase (1980–2005).

Feldman, K. W., & Brewer, D. K. (1984). Child abuse, cardiopulmonary resuscitation and rib fractures. *Pediatrics*, *73*(3), 339–342.

Garcia, V. F., Gotschall, C. S., Eichelberger, M. R., & Bowman, L. M. (1990). Rib fractures in children: a marker of severe trauma. *The Journal of Trauma*, *30*(6), 695–700.

Gunther, W. M., Symes, S. A., & Berryman, H. E. (2000). Characteristics of child abuse by anteroposterior manual compression versus cardiopulmonary resuscitation: case reports. *American Journal of Forensic Medicine and Pathology*, *21*(1), 5–10.

Ingram, J. D., Connell, J., Hay, T. C., Strain, J. D., Mackenzie, T., & Mueller, C. F. (2000). Oblique radiographs of the chest in nonaccidental trauma. *Emergency Radiology*, *7*(1), 42–46.

ISI Proceedings (1990–2005).

Kleinman, P., & Schlesinger, A. (1997). Mechanical factors associated with posterior rib fractures: laboratory and case studies. *Pediatric Radiology*, *27*, 87–91.

Kleinman, P. K., Marks, S. C., Adams, V. I., & Blackbourne, B. D. (1988). Factors affecting visualization of posterior rib fractures in abused infants. *American Journal of Roentgenology*, *150*(3), 635–638.

Kleinman, P. K., Marks, S. C., Spevak, M. R., & Richmond, J. M. (1992). Fractures of the rib head in abused infants. *Radiology*, *185*, 119–123.

Klotzbach, H., Delling, G., Richter, E., Sperhake, J. P., & Puschel, K. (2003). Post-mortem diagnosis and age estimation of infants' fractures. *International Journal of Legal Medicine*, *117*(2), 82–89.

Kouwenhouven, W. B., Jude, J. R., & Knickerbocker, C. G. (1960). Closed-chest cardiac massage. *The Journal of the American Medical Association*, *173*(10), 1094–1097.

Leventhal, J. M., Thomas, S. A., Rosenfield, N. S., & Markowitz, R. I. (1993). Fractures in young children. Distinguishing child abuse from unintentional injuries. *American Journal of Diseases of Children*, *147*(1), 87–92.

McClelland, C. Q., & Heiple, K. G. (1982). Fractures in the first year of life: a diagnostic dilemma? *American Journal of Diseases of Children*, *136*, 26–29.

Medline (1950–2005).

Medline In-Process (2005).

Nadkarni, V., Hazinski, M. F., Zideman, D., Kattwinkel, J., Quan, L., Bingham, R., Zaritsky, A., Bland, J., Kramer, E., & Tiballs, J. (1997). Paediatric life support. An advisory statement by the paediatric life support working group of the international liaison committee on resuscitation. *Resuscitation*, *34*(2), 115–127.

NHS Centre for Reviews and Dissemination (2001). Undertaking systematic reviews of research on effectiveness. CRD's guidance for those carrying out or commissioning reviews CRD report no. 4 (2nd ed.). University of York.

Parke, T. (1993). Unexplained pneumoperitoneum in association with basic cardiopulmonary resuscitation efforts. *Resuscitation*, *26*(2), 177–181.

Powner, D. J., Holcombe, P. A., & Mello, L. A. (1984). Cardiopulmonary resuscitation-related injuries. *Critical Care Medicine*, *12*(1), 54–55.

Price, E., Rush, L., Perper, J., & Bell, M. (2000). Cardiopulmaonary resuscitation-related injuries and homicidal blunt trauma in children. *The American Journal of Forensic Medicine and Pathology*, *21*(4), 307–310.

Patel, R. v. (2003).

Ryan, M. P., Young, S. J., & Wells, D. L. (2003). Do resuscitation attempts in children who die, cause injury? *Emergency Medicine Journal*, *20*(1), 10–12.

Saternus, K.-S., & Oehmichen, M. (1985). Kardiopulmonale reanimation bei säuglingen (cardiopulmonary resuscitation in infants). *Der Notarzt*, *1*, 77–81.

Schweich, P., & Fleisher, G. (1985). Rib fractures in children. *Pediatric Emergency Care*, *1*, 187–189.

Science Citation Index Expanded (1981–2005).

Sewell, R. D., & Steinberg, M. A. (2000). Chest compressions in an infant with osteogenesis imperfecta type II: no new rib fractures. *Pediatrics*, *106*(5), E71.
SIGLE (1980–2005).
Social Science Citation Index (1981–2005).
Spevak, M. R., Kleinman, P. K., Belanger, P. L., Primack, C., & Richmond, J. M. (1994). Cardiopulmonary resusciation and rib fractures in infants: a postmortem radiologic–pathologic study. *The Journal of the American Medical Association*, *272*(8), 617–618.
Strouse, P. J., & Owings, C. L. (1995). Fractures of the first rib in child abuse. *Radiology*, *197*(3), 763–765.
Thaler, M. M., & Krause, V. W. (1962). Serious trauma in children after external cardiac massage. *The New England Journal of Medicine*, *267*(10), 500–501.
Thomas, P. S. (1977). Rib fractures in infancy. *Annales de Radiologie*, *20*(1), 115–120.
TRIP (1997–2005).

Résumé

Contexte : Il existe une interrogation diagnostique quand un enfant présente des fractures de côtes aprés une resuscitation cardio-pulmonaire (RCP) et si une maltraitance infantile est suspectée d'être la cause du collapsus. Nous avons effectué une revue systématique pour établir une base de preuve pour les questions suivantes: (1) La resuscitation cardio-pulmonaire provoque-t'elle des fractures de côtes chez les enfants? (2) Si c'est le cas, quelles sont la fréquence et les caractéristiques de ces fractures qui pourraient aider à les distinguer des fractures de côtes provoquées par une maltraitance physique?
Méthodes : Nous avons réalisé une recherche dans la littérature d'articles originaux, de références, de manuels, et de résumés de conférences, publiés dans toutes les langues de 1950 au 1er octobre 2005. Des articles ont été découverts dans ASSIA, Caredata, Medline, Ovid Medline in process, ChildData, CINAHL, Embase, ISI Proceedings, SIGLE, Science Citation Index, Social Science Citation index, et les bases de données TRIP. Nous avons inclu toutes les etudes qui abordaient les fractures de côtes et une RCP chez des enfants de moins de 18 ans, et exclu les articles de revue, les opinions d'experts, les consensus de conduites à tenir, et les études qui, de façon significative étaient systématiquement accompagnées d'une appréciation critique. Chaque étude a été soumise à deux enquêtes indépendantes (avec une troisième en cas de désaccord). Chaque enquêteur a utilisé des critères standardisés pour la définition de l'étude, la prise en compte des données, et l'appréciation critique, pour déterminer la qualité de l'étude et décider si elle correspondait aux critères d'inclusion de cette revue systématique.
Constatations : Sur les 427 études passées en revue, 6 ont été inclues: 1 étude contrôle, 4 études de références croisées, et une sur des séries. Elles comportent les observations de 923 enfants qui ont subi une RCP. Trois enfants ont subi des fractures de côtes suite à une resuscitation; tous les 3 avaient des fractures qui étaient antérieures (2 medio-claviculaires, et une chondro-costale). Dans la littérature nous n'avons trouvé aucun enfant qui avait une fracture costale postérieure secondaire à une RCP. Les resuscitations avaient été réalisées à la fois par du personnel medical et non médical.
Conclusion : Les fractures de côtes aprés resuscitation cardio-pulmonaire sont rares. Quand elles surviennent, elles sont antérieures et peuvent être multiples. Comme les études anciennes n'ont pas utilisé les techniques les plus sensibles pour la détection de fractures de côtes, d'autres etudes prospectives d'enfants seraient intéressantes pour fournir une clarification supplémentaire sur ce sujet.

Resumen

Planteamiento del problema: Existe un dilema diagnóstico cuando un niño presenta fracturas de las costillas después de una resucitación cardiopulmonar (CPR) cuando se sospecha que la causa del colapso fue abuso contra el niño. Hemos realizado una revisión sistemática para establecer la base de evidencia para responder a las siguientes preguntas: (1) ¿Puede la resucitación cardiopulmonar ocasionar fracturas en las costillas en los niños? (2) Si es así, ¿Cuáles son las frecuencias y las características de esas fracturas que pueden ayudar a distinguirlas de las fracturas ocasionadas por el abuso físico?
Métodos: Realizamos una revisión de artículos originales, referencias, libros de texto y resúmenes de conferencias, publicados en cualquier idioma desde 1950 hasta Octubre 1ro., 2005. Los artículos se identificaron de ASSIA, Caredata, Medline, Ovid Medline en Proceso, ChildData, CINAHL, Embase, ISI Procedimientos, SIGLE, Indice de Citas Científicas, Indice de Citas de Ciencia Social, y base de datos de TRIP. Incluímos todos los estudios que enfocaban las fracturas de costillas y el CPR en niños menores de 18 años, y excluímos revisión de artículos, opiniones de expertos, líneas de consenso y estudios que fueran considerados por la evaluación crítica como significativamente inadecuados metodológicamente. Cada estudio pasó por dos revisiones independientes (con una tercera revisión si hay desacuerdo). Cada evaluador utilizó un criterio estandarizado para estudiar la definición, recogida de los datos, y evaluación crítica, para determinar la calidad del estudio y para establecer si responde a los criterios de inclusión de esta revisión sistemática.
Hallazgos: De los 427 estudios revisados, 6 fueron incluidos: 1 control de caso, 4 estudios transversales y 1 caso de serie. Estos representan datos de 923 niños que fueron sometidos a CPR. Tres niños sufrieron fracturas de las costillas como resultado de la resucitación; los tres tenían fracturas que aparecieron anteriormente (2 clavícula media y 1 costo-condrial). No encontramos niños en la literatura que presentaran una fractura de costilla posterior debido al CPR. La resucitación fue implementada tanto por personal médico como no médico.
Conclusión: Las fracturas de costilla después de resucitación caardiopulmonar (CPR) son raras. Cuando ocurren, son anteriores y pueden ser múltiples. Como los estudios realizados a la fecha no utilizaron las técnicas más sensibles para detectar las fracturas de costillas, sería valioso realizar más estudios prospectivos de niños para obtener clarificaciones valiosas sobre este tema.