WORKSHEET for Evidence-Based Review of Science for Emergency Cardiac Care

Worksheet author(s)

Anton P. M. Gorgels Antonius M. W. van Stipdonk	**Date Submitted for review:** November 3d, 2009

Clinical question.

In adults and pediatric patients who are NOT in cardiac arrest (P), how often does provision of chest compressions from lay rescuers (I), lead to harm (eg rib fracture) (O)?

Is this question addressing an intervention/therapy, prognosis or diagnosis? Intervention
State if this is a proposed new topic or revision of existing worksheet: new topic

Conflict of interest specific to this question

Do any of the authors listed above have conflict of interest disclosures relevant to this worksheet? No

Search strategy (including electronic databases searched).

Terms and limitations in 3 different databases; PUBMED, EMBASE, COCHRANE LIBRARY

1. **PUBMED**: Mesh searchterms

"Cardiopulmonary Resuscitation/adverse effects"[Mesh])) AND "Thoracic Injuries"[Mesh]; no limitations
HITS 44
Manual screening title and abstract: 32 relevant publications, 1 extra finding by endnote, all available

2. **EMBASE**: Advanced OVID search

'resuscitation' (all subheadings) AND 'thoracic injury' (all subheadings); no limitations
HITS 227
Manual screening title and abstract: 22 relevant publications, 1 extra finding by endnote, 1 not available

3. **COCHRANE LIBRARY**: search by topic;

'HEART' – 'HEART ARREST' - 'NON-DRUGS' (3):
HITS 1
Active chest compression-decompression for cardiopulmonary resuscitation (review)

4. **Expert consultation (publications retrieved through consultation of experts in the field):**

Berdowski 2009
Flynn 2006
Garza 2003
Hallstrom 2003
Krischer 1987
Lopez-Herce 2004
Nurmi 2006
Oschatz 2001
Peberdy 2006

- **State inclusion and exclusion criteria**

Inclusion criteria

Involving human subjects of any age (including children and infants), with suspected or diagnosed cardiac arrest, treated with any form of CPR involving chest compressions, provided by any person (lay or professional), complicated by any form of thoracic injury.

Exclusion criteria

studies involving
animals

manikins
• **Number of articles/sources meeting criteria for further review:**
65 publications*
*Not all original publications will be found as reference in text, because of them being part of systematic review papers..

Summary of evidence

Evidence Supporting Clinical Question

Good					
Fair					Garza et al. 2003 Nurmi et al. 2006 Flynn et al. 2006 Berdowski et al. 2009 Lederer et al. 2004 Nishida et al. 2006 Baubin et al. 1999 Black et al. 2004
Poor					Hashimoto et al. 2007 Robertson & Holmberg. 1992
	1	**2**	**3**	**4**	**5**
Level of evidence					

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = Other endpoint
Italics = Animal studies

Evidence Neutral to Clinical question

Good					Lafuente-Lafuente & Melero-Bascones, 2004 Hoke & Chamberlain. 2004
Fair					
Poor					Buschmann & Tsokos 2009
	1	**2**	**3**	**4**	**5**
Level of evidence					

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = Other endpoint
Italics = Animal studies

Evidence Opposing Clinical Question

Good					Maguire et al. 2006 Dolinak. 2007
Fair				White et al. 2010	Peberdy et al. 2006 Oschatz et al. 2001
Poor				Hallstrom et al. 2003	
	1	**2**	**3**	**4**	**5**
Level of evidence					

A = Return of spontaneous circulation
B = Survival of event
C = Survival to hospital discharge
D = Intact neurological survival
E = Other endpoint
Italics = Animal studies

REVIEWER'S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK:

Circumstantial literature on resuscitation and on subjects in actual cardiac arrest was used to assess complications of resuscitation, and literature on dispatcher guided resuscitation on complications of resuscitation in victims not in cardiac arrest. This literature suggests that 1. thoracic injuries are a frequent complication of resuscitation in cardiac arrest, 2. female victims and victims at older age are more prone to chest injuries, whereas children are less affected, 3. resuscitation by lay rescuers does not lead to increased risk of injuries as compared to resuscitation by professionals, 4. the risk of starting resuscitation in victims not in cardiac arrest is high, as suggested by literature on dispatcher guided resuscitation. 5. One study specifically addressed the topic of subjects not in actual cardiac arrest and resulting thoracic injury (White et al. 2010)(LOE 4, fair) and in one other study reporting on this question, this was not the primary study focus (Hallstrom et al. 2003) (LOE 4, poor) . Both studies reported no severe adverse sequelae. However both studies regarded dispatcher guided CPR population, therefore not representing the full target population.

Thoracic injuries caused by resuscitation in adults in cardiac arrest:

Rib fractures
A systematic review of complications in conventional CPR reveals that rib fractures occur in 13-97% of cases. Average number of rib fractures per case is 5 to 8. In all studies the left side of the chest was more frequently involved than the right side. More than 2/3 of cases with a rib fracture have multiple rib fractures. Rib fractures usually (89%) occur in ribs 2 – 7. Posterior thoracic fractures are exceptional as a complication of CPR (Hoke and Chamberlain 2004; Buschmann and Tsokos 2009).
Two recent focused autopsy studies, not included in the review, reported on rib fractures: an incidence of rib fractures in 89% were found in a very small number of patients (n =19) (Lederer, Mair et al. 2004), whereas 29% rib fractures were reported in a much larger population of 499 unsuccesful CPR's for unexpected, uncertified deaths or deaths of unnatural causes, without any history or physical evidence of trauma (Black, Busuttil et al. 2004).

A narrative review by Buschmann and Tsokos (2009) on autopsy cases shows studies to report rib or sternal fractures to occur in 13 – 97% of cases. Rib fractures are more prevalent on the left side, mostly the 2nd – 7th rib, in the midclavicular line (Buschmann and Tsokos 2009).

Sternal fractures
A systematic review of the occurrence of complications in conventional CPR reveals that sternal fractures occur in 1 – 43% of cases. The exact location is rarely studied and results are heterogenic (Hoke and Chamberlain 2004). A focused autopsy study not included in the review reported a frequency of 49% of sternal fractures in unsuccesful out-of-hospital resuscitations in 19 patients (Lederer, Mair et al. 2004). Another retrospective autopsy record review of 499 cases of unexpected, uncertified deaths or deaths of unnatural causes after unsuccesful CPR, without any history or physical evidence of trauma reports a frequency of sternal fractures of 14% (Black, Busuttil et al. 2004).

High risk groups for thoracic injury during cardiopulmonary resuscitation
Rib fractures are more common in elderly (Robertson and Holmberg 1992; Black, Busuttil et al. 2004; Hoke and Chamberlain 2004; Buschmann and Tsokos 2009) and in women (Black, Busuttil et al. 2004), whereas the higher occurrence of sternal fractures in women is not clear, given the trend to significance in one study (Black, Busuttil et al. 2004) and no more fractures in women in another one (Baubin, Sumann et al. 1999).

Effect of device assisted cardiopulmonary resuscitation: active compression-decompression (ACD) cardiopulmonary resuscitation as compared to standard resuscitation.

The systematic review by Hoke & Chamberlain (2004) summarizes the results of 6 studies including at least results on 15 cases. This review showed a 3.8 – 86.6% incidence for rib fractures and 0 -93.3% incidence for sternal fractures. The review concluded that there was no compelling evidence on an increased complication rate in ACD assisted CPR (Hoke and Chamberlain 2004).
A recent Cochrane review studied the occurrence of complications in ACD-CPR versus S-CPR studied in 10 randomised or quasi-randomised trials and concluded no difference in sternal or rib fractures, nor rare sequelae such as pneumo- or haematothorax (Lafuente-Lafuente and Melero-Bascones 2004).

Thoracic injuries caused by resuscitation in children in cardiac arrest:

A recent review (Buschmann & Tsokos, 2009) concludes that in general resuscitation related injuries are rarely observed in children (Buschmann and Tsokos 2009).

Rib fractures
In a systematical review by Maguire, Mann et al. (2006) 6 studies were identified (1 case-control, 4 cross-sectional, and 1 case series) studying complications of resuscitation in children (n=923, 0-14 yr). Resuscitation was performed by both medical and non-medical personnel. Of 923 cases, in 3 rib fractures were found (0-2%), all on the anterior thoracic wall. Limitations to the conclusions of this review are retrospective designs of the studies in it, small numbers of cases and considerable heterogeneity (Maguire, Mann et al. 2006). Another narrative review confirms this conclusion (Hashimoto, Moriya et al. 2007). In a systematical review by Hoke & Chamberlain (2004) identified 5 studies in complications of CPR in children, reported 0-2% rib fractures in children (Hoke and Chamberlain 2004). Another study, not included in the reviews, reported of 70 consecutive autopsies in infants (2 weeks – 8 months old) showing rib fractures in 11% of cases after rescusitation and in 7 of 8 cases multiple rib fractures (up to 10) (Dolinak 2007).

Sternal fractures
In a systematical review by Hoke & Chamberlain (2004) identified 5 studies in complications of CPR in children, containing no report of sternal fractures (Hoke and Chamberlain 2004).

Rare sequelae of thoracic injuries during resuscitation

In the review of Hoke & Chamberlain (2004), although not a primary objective, internal or other thoracic complications are reported:

- Pulmonary bone marrow embolism, reported in 0.4 – 26.9% of cases (7 studies)
- Left ventricular haemorrhage, reported in 0 – 8% of cases (3 studies)
- Pneumothorax, reported in 1.3 – 3.0% of cases (5 studies)
- Haematothorax, reported in 0.8 – 8.7% of cases (5 studies)
- Hepatic laceration/rupture, reported in 0.8 – 4.3% of cases (4 studies)
- Haemopericard, reported in 1.1 – 8.4% of cases (5 studies)
- Aortic laceration, reported in 0.5 – 1.6% of cases (2 studies)
- Splenic laceration/rupture, reported in 0.3 – 2.6% of cases (4 studies)

In a more recent non-systematic review of Buschmann & Tsokos (2009) reports of rhabdomyolysis and myoglobulinuric renal failure, injuries of the diaphragm are added to the complications mentioned above (Buschmann and Tsokos 2009). Also evidence has been reported on affecting the cardiac conduction system due to resuscitation efforts (Nishida, Chiba et al. 2006).

Resuscitation induced thoracic injuries by lay rescuers

The evidence on the absence of abundant complications in resuscitation by lay rescuers is supported by 2 studies. Using chest radiography one study compared the occurrence of injuries in victims treated with bystander basic life

support with victims only receiving advanced life support. No increase of injuries were found in the group receiving bystander support (Oschatz, Wunderbaldinger et al. 2001). The other study reported on the number of adverse events in more than 20.000 lay volunteers participating in a public access AED program comparing CPR only with CPR plus AED. Only 2 patient-related adverse events were reported, both regarding rib fractures (Peberdy, Ottingham et al. 2006).

Resuscitation induced thoracic injuries by lay rescuers in victims not in cardiac arrest

Incidence of adverse sequelae of starting resuscitation in patients not in cardiac arrest
Data from literature on dispatcher guided resuscitation reveal a high false positivity rate in diagnosing cardiac arrest, varying between 16-41,6%, thereby causing overtreatment of subjects not in cardiac arrest (Garza, Gratton et al. 2003; Hallstrom, Cobb et al. 2003; Flynn, Archer et al. 2006; Nurmi, Pettila et al. 2006; Berdowski, Beekhuis et al. 2009,).
However, lay resuscitation does not appear to cause extensive damage in subjects not in cardiac arrest:
In one study on dispatcher guided CPR relevant to the question, 1/6 calls were erroneously classified as cardiac arrests. Completion of CPR instructions by these untrained bystanders occurred in 1/3 (71/190) up to arrival of the ambulance. However no serious adverse sequelae were reported (Hallstrom, Cobb et al. 2003).
In one other study, specifically aimed at identifying injury in victims receiving dispatcher guided CPR, while not being in cardiac arrest, of a total of 247 victims 12% experienced discomfort, 2% suffered a fracture and no visceral organ injury occurred (White, Rogers et al. 2010).

Discussion

Because studies on complications of resuscitation are frequently performed in unsuccessful resuscitation cases and autopsy cases, complication rates may be exaggerated. Generally the duration of resuscitation is longer in unsuccessful cases and therefore complication rates could be lower in survivors.
Nevertheless, in survivors many rib or sternal fractures will be missed, because of the difficulties with radiographic diagnostics (Lederer, Mair et al. 2004). Furthermore, complications may be asymptomatic and remain undetected.

It is reasonable to assume that complications of resuscitation efforts in patients not actually in cardiac arrest should be less severe because of early recurrence of vital signs and therefore cessation of resuscitation efforts. From practical experience and general expectations it is likely that the duration of resuscitation efforts in subjects not actually in cardiac arrest is shorter and therefore results in less complications than in victims, indeed in cardiac arrest. This is supported by the 2 studies reporting on this question, one being specifically aimed at studying this. However in both studies it concerned dispatcher guided CPR by untrained bystanders, being not fully representative for all lay rescuers providing CPR.

Acknowledgements:

Citation List

Baubin, M., G. Sumann, et al. (1999). "Increased frequency of thorax injuries with ACD-CPR." Resuscitation **41**(1): 33-8.

LOE 5, fair, supportive

In a prospective randomised trial with a small number of out-of-hospital resuscitations actually designed to compare different techniques of chest compression during CPR, it was reported on the number of sternal and rib fractures occurring as complications in CPR performed on patients actually in cardiac arrest and performed by professionals.

Berdowski, J., F. Beekhuis, et al. (2009). "Importance of the first link: description and recognition of an out-of-hospital cardiac arrest in an emergency call." Circulation **119**(15): 2096-102.

LOE 5, fair, supportive.

Prospective study from the Netherlands as to the accuracy of dispatchers to recognize out-of-hospital cardiac arrest and the relation with outcome. The study was included because it showed 24% of suspected calls regarding victims not being in cardiac arrest, supporting the idea of the frequent occurrence of starting resuscitation efforts in individuals not in cardiac arrest.

Black, C. J., A. Busuttil, et al. (2004). "Chest wall injuries following cardiopulmonary resuscitation." Resuscitation **63**(3): 339-43.

LOE 5, fair, supporting

A retrospective record-study, designed to study complications of CPR, reporting on a large number of non-successful CPR with specifications of susceptibility of different patient groups and different anatomical regions. The provider of CPR was not stated, nor were cases included not in actual cardiac arrest.

Buschmann, C. T. and M. Tsokos (2009). "Frequent and rare complications of resuscitation attempts." Intensive Care Med **35**(3): 397-404.

LOE 5, poor, neutral

A retrospective review of a large number of autopsy cases of non-succesful CPR, reporting on specifications of susceptibility of different patient groups and different anatomical regions. The provider of CPR was not stated, nor were cases included not in actual cardiac arrest.

Dolinak, D. (2007). "Rib fractures in infants due to cardiopulmonary resuscitation efforts." Am J Forensic Med Pathol **28**(2): 107-10.

LOE 5, fair, opposing

Series of a reasonable number of autopsy cases of non-successful CPR in children, stating the low incidence and specific patterns of anatomical distribution, but not reporting the provider of CPR, nor including cases not in actual cardiac arrest.

Flynn, J., F. Archer, et al. (2006). "Sensitivity and specificity of the medical priority dispatch system in detecting cardiac arrest emergency calls in Melbourne." Prehosp Disaster Med **21**(2): 72-6.

LOE 5, fair, supporting

A retrospective study from Melbourne, Australia, as to the sensitivity and specificity of a medical priority dispatch system to recognize out-of-hospital cardiac arrest. The study was included because it showed 41,6% of suspected calls regarding victims not being in cardiac arrest, supporting the idea of the frequent occurrence of starting resuscitation efforts in individuals not in cardiac arrest.

Garza, A. G., M. C. Gratton, et al. (2003). "The accuracy of predicting cardiac arrest by emergency medical services dispatchers: the calling party effect." Acad Emerg Med **10**(9): 955-60.

LOE 5, fair, supportive

A retrospective study from Missouri as to the accuracy of dispatchers to recognize out-of-hospital cardiac arrest depending on the type of caller. The study was included because it showed 35% of suspected calls regarding victims not being in cardiac arrest, supporting the idea of the frequent occurrence of starting resuscitation efforts in individuals not in cardiac arrest.

Hallstrom, A. P., L. A. Cobb, et al. (2003). "Dispatcher assisted CPR: implementation and potential benefit. A 12-year study." Resuscitation **57**(2): 123-9.

LOE 4, poor, opposing

A retrospective study from Seattle as to the accuracy of dispatchers to recognize out-of-hospital cardiac arrest and the resulting potential of benefit of dispatcher assisted CPR. The study was included because it showed 16% of suspected calls regarding victims not being in cardiac arrest, supporting the idea of the frequent occurrence of starting resuscitation efforts in individuals not in cardiac arrest. The study also reported no severe sequelae in victims receiving CPR but being in cardiac arrest.

Hashimoto, Y., F. Moriya, et al. (2007). "Forensic aspects of complications resulting from cardiopulmonary resuscitation." Leg Med (Tokyo) **9**(2): 94-9.

LOE 5, fair, supporting (adults), good, opposing (children)

Non systematic review of complications of CPR in adults and children and report of own results in adults, primarily designed to investigate the differentiation of iatrogenic trauma from deliberate trauma. The provider of CPR was not stated, nor were cases included not in actual cardiac arrest.

Hoke, R. S. and D. Chamberlain (2004). "Skeletal chest injuries secondary to cardiopulmonary resuscitation." Resuscitation **63**(3): 327-38.

LOE 5, good, neutral

Systematic review of skeletal chest injuries in adults and children secondary to CPR, mainly focusing on conventional CPR versus active compression-decompression CPR. The provider of CPR was not stated, nor were cases included not in actual cardiac arrest.

Lafuente-Lafuente, C. and M. Melero-Bascones (2004). "Active chest compression-decompression for cardiopulmonary resuscitation." Cochrane Database Syst Rev(2): CD002751.

LOE 5, good, neutral

Good quality systematic review of randomised and quasi-randomised controlled trials focusing on the difference between conventional versus active compression-decompression CPR. No cases were included not in actual cardiac arrest

Lederer, W., D. Mair, et al. (2004). "Frequency of rib and sternum fractures associated with out-of-hospital cardiopulmonary resuscitation is underestimated by conventional chest X-ray." Resuscitation **60**(2): 157-62.

LOE 5, fair, supporting

Prospective study of a small number of unsuccessful CPR cases, with the main purpose of studying the accuracy of chest X-ray in diagnosing rib fractures as compared to autopsy. The provider of CPR was not stated, nor were cases included not in actual cardiac arrest.

Maguire, S., M. Mann, et al. (2006). "Does cardiopulmonary resuscitation cause rib fractures in children? A systematic review." Child Abuse Negl **30**(7): 739-51.

LOE 5, good, opposing

Systematic review of studies reporting on complications of non-succesful CPR in children, performed by professional as well as non-professional individuals. The study reported on incidence and anatomical specifications of rib fractures. No cases were included not in actual cardiac arrest.

Nishida, N., T. Chiba, et al. (2006). "Relationship between cardiopulmonary resuscitation and injuries of the cardiac conduction system: pathological features and pathogenesis of such injuries." Crit Care Med **34**(2): 363-7.

LOE 5, fair, supporting

Prospective autopsy studie examinating complications of CPR on the cardiac conduction system, reporting on limited injuries to the conduction system. It regarded cases of non-successful CPR attempts. The provider of CPR was not stated, nor were cases included not in actual cardiac arrest.

Nurmi, J., V. Pettila, et al. (2006). "Effect of protocol compliance to cardiac arrest identification by emergency medical dispatchers." Resuscitation **70**(3): 463-9.

LOE 5, fair, supportive

A prospective study from Finland as to the accuracy of dispatchers to identify out-of-hospital cardiac arrest in relation to dispatcher's protocol compliance. The study was included because it showed 61,9% of suspected calls regarding victims not being in cardiac arrest, supporting the idea of the frequent occurrence of starting resuscitation efforts in individuals not in cardiac arrest.

Oschatz, E., P. Wunderbaldinger, et al. (2001). "Cardiopulmonary resuscitation performed by bystanders does not increase adverse effects as assessed by chest radiography." Anesth Analg **93**(1): 128-33.

LOE 5, fair, opposing

Prospective study of a fair number of successful cases of conventional CPR in patients in cardiac arrest. Reporting no difference of complications in between CPR performed by bystanders or professionals as assessed by chest x-ray. Supporting the comparability of incidence of complications reported in an abundance of studies of professional provided CPR. Not including cases not in actual cardiac arrest.

Peberdy, M. A., L. V. Ottingham, et al. (2006). "Adverse events associated with lay emergency response programs: the public access defibrillation trial experience." Resuscitation **70**(1): 59-65.

LOE 5, fair, opposing

The study reports on the occurrence of adverse events in victims receiving CPR in a large public access defibrillation program. Public places were randomized to provide BLS only or BLS-AED. The incidence of adverse events was found to be low. However the study was not specifically designed to study adverse events imposed by lay rescuers, nor to study the occurrence of adverse events in victims receiving CPR but not being in cardiac arrest.

Robertson, C. and S. Holmberg (1992). "Compression techniques and blood flow during cardiopulmonary resuscitation. A statement for the Advanced Life Support Working Party of the European Resuscitation Council." Resuscitation **24**(2): 123-32.

LOE 5, poor, supportive

Narrative review (European Resuscitation Counsil) of consequences of different compression techniques during CPR, primarily focusing on efficacy of restoring blood flow, but also taking into account complications of different techniques. The study therefore reported on thoracic complications of closed chest CPR, with an expert consensus on the higher frequency in elderly patients .

White, L, Rogers, J., et al. "Dispatcher-assisted cardiopulmonary resuscitation: risks for patients not in cardiac arrest" Circulation jan 5 121 (1): 91-7

LOE 4, fair, opposing.

A prospective cohort study from King County, Washington as to the accuracy of dispatchers to recognize out-of-hospital cardiac arrest and the resulting harm to the individuals not in arrest, receiving dispatcher guided bystander CPR. The study was included because it showed 45% of suspected calls regarding victims not being in cardiac arrest, supporting the idea of the frequent occurrence of starting resuscitation efforts in individuals not in cardiac arrest. It also was the only study specifically addressing the worksheet question and supported the idea that harm for victims not in arrest but receiving CPR is low. It concerned however untrained bystanders, likely not being representative for all lay BLS providers.