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Active chest compression-decompression for cardiopulmonary resuscitation (Review)

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[Intervention Review]

Active chest compression-decompression for cardiopulmonary resuscitation

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ABSTRACT

Background

Active compression-decompression cardiopulmonary resuscitation (ACDR CPR) uses a hand-held suction device, applied mid-sternum, to compress the chest then actively decompress the chest after each compression. Randomised controlled trials testing this device have shown discordant results.

Objectives

To determine the effect of active chest compression-decompression CPR compared to standard chest compression CPR on mortality and neurological function in adults with cardiac arrest treated either in-hospital or out-of-hospital.

Search methods

We updated the searches of CENTRAL in *The Cochrane Library* (Issue 12 of 12, 2012), MEDLINE (OVID, 1946 to January week 1 2013), and EMBASE (OVID, 1980 to week 1 2013) on 14 January 2013. We checked the reference list of retrieved articles, contacted experts in the field, and searched ClinicalTrials.gov.

Selection criteria

All randomised or quasi-randomised studies comparing active compression-decompression with standard manual chest compression in adults with a cardiac arrest who received cardiopulmonary resuscitation by a trained medical or paramedical team.

Data collection and analysis

We independently extracted data on an intention-to-treat basis. When needed, we contacted the authors of the primary studies. If appropriate, we cumulated studies and pooled relative risk (RR) estimates. We predefined subgroup analyses according to setting (out-of-hospital or in-hospital) and attending team composition (with physician or paramedic only).

Main results

In this update, 27 new related publications were found, but they did not all fulfil inclusion criteria or concerned participants already reported in previous publications. In the end, we included 10 trials in this review: Eight were in out-of-hospital settings; one was set in-hospital only; and one had both in-hospital and out-of-hospital components. Allocation concealment was adequate in four studies. The

two in-hospital studies were different in quality and size (773 and 53 participants). Both found no differences between ACDR CPR and STR in any outcome.

Out-of-hospital trials cumulated 4162 participants. There were no differences between ACDR CPR and STR for mortality either immediately (RR 0.98, 95% confidence interval (CI) 0.94 to 1.03) or at hospital discharge (RR 0.99, 95% CI 0.98 to 1.01). The pooled RR of neurological impairment of any severity was 1.71 (95% CI 0.90 to 3.25), with a non-significant trend to more frequent severe neurological damage in survivors of ACDR CPR (RR 3.11, 95% CI 0.98 to 9.83). However, assessment of neurological outcome was limited, and few participants had neurological damage.

There was no difference between ACDR CPR and STR with regard to complications such as rib or sternal fractures, pneumothorax, or haemothorax (RR 1.09, 95% CI 0.86 to 1.38). Skin trauma and ecchymosis were more frequent with ACDR CPR.

Authors' conclusions

Active chest compression-decompression in people with cardiac arrest is not associated with any clear benefit.

PLAIN LANGUAGE SUMMARY

Active compression-decompression using a hand-held device for emergency heart massage

During standard cardiopulmonary resuscitation (heart massage) for cardiac arrest (arrest of the heart), the chest is compressed manually and repeatedly by hand. This is a temporary method that pumps blood and oxygen to the brain via the heart. During standard cardiopulmonary resuscitation, the chest is not manually decompressed. Active chest compression-decompression is an alternative method of heart massage and uses a hand-held suction device to compress the chest, then decompress the chest after each compression. Comparison of these techniques showed active chest compression-decompression to have no advantage and some drawbacks compared to standard cardiopulmonary resuscitation.

BACKGROUND

Active compression-decompression resuscitation (ACDR CPR) uses a hand-held device with a suction cup to perform cardiac massage during cardiopulmonary resuscitation. The operator applies this device mid-sternum to compress the chest as in standard manual cardiopulmonary resuscitation (STR). The operator then uses the device to actively decompress the chest after each compression (Cohen 1992). This differs from STR, which allows passive relaxation of the chest after each compression. A pressure gauge in the device measures both compression and decompression forces and can be used to adjust the effort.

ACDR CPR was designed to increase the pump action of closed chest massage. Indeed, experimental studies have shown that ACDR CPR, in comparison to STR, increases venous return and left ventricular filling in the decompression phase, leading to improved stroke volume (Tucker 1993), cardiac output (Orliaguet 1995), and arterial pressures (Shultz 1994) in the compression phase. Only one study, involving participants after prolonged resuscitation, found no differences in haemodynamics (Malzer 1996).

Disadvantages of ACDR CPR include the requirement for more training than STR, more physical effort (Shultz 1995), and the fact that it can be more difficult to apply in certain clinical situations. Increased frequency of sternal and rib fractures with ACDR CPR has been reported (Baubin 1999).

The improved haemodynamic associated with ACDR CPR was expected to reduce mortality or neurological damage, or both, when applied to people in cardiac arrest. However, results from clinical trials have been variable and contradictory. The first clinical trials comparing ACDR CPR to STR included small groups of participants, in-hospital, and showed promising results with the newer technique (Cohen 1993; Tucker 1994). Later randomised controlled trials involving a greater number of participants, mostly in out-of-hospital settings, often showed negative effects for the ACDR CPR method (Schwab 1995; Stiell 1996).

Mauer et al combined individual participant data of 2866 participants from seven separate out-of-hospital randomised controlled trials (Mauer 1999). Pooled data showed in participants treated with ACDR CPR a significant improvement in one-hour survival (23.8% versus (vs) 20.6% in ACDR CPR and STR groups, respectively) and a trend, which was not significant, towards a better survival to hospital discharge (7% vs 5.8%). Mauer et al found that ACDR CPR neither improved nor impaired neurological outcomes and complication rates. After the publication of this meta-analysis, several new controlled trials comparing ACDR CPR and STR were done. Again, some showed a benefit using ACDR CPR (Plaisance 1999), and some did not (Skogvoll 1999).

A parallel Cochrane systematic review, which aimed to study the effectiveness of mechanical chest compression devices when compared with manual chest compressions for cardiopulmonary resuscitation, found that evidence from human studies was insufficient to conclude that mechanical chest compression is associated with benefit or harm (Brooks 2011). ACDR CPR is a passive tool, manually driven by the rescuer, who delivers all the energy needed to compress and decompress the chest, so it is as prone - or more - to fatigue as standard manual compression. The 2010 American Heart Association guidelines for cardiopulmonary resuscitation increased the focus on adequate

chest compression as a critical component of high-quality cardiopulmonary resuscitation (American Heart Association 2010). Retrieving the ACDR CPR device might delay immediate application of chest compression, and early fatigue may reduce the performance of compressions performed with this device.

We decided to prepare and maintain a systematic review, analysing the effects of the use of ACDR CPR and STR in both out-of-hospital and in-hospital settings.

OBJECTIVES

To determine the effect of active chest compression-decompression CPR compared to standard chest compression CPR on mortality and neurological function in adults with cardiac arrest treated either in-hospital or out-of-hospital.

METHODS

Criteria for considering studies for this review

Types of studies

Randomised or quasi-randomised controlled trials comparing ACDR CPR to STR in the defined population and reporting at least one of the defined outcomes. We accepted quasi-randomised studies because it can be difficult to maintain the allocation process, as the time available for deciding treatment is very limited. Double-blinding is not possible for this intervention; blinded assessment of outcomes was desired, but we did not consider it a decisive requisite for inclusion of studies.

Types of participants

Adult patients (any age greater than 16 years old) suffering cardiac arrest and undergoing cardiopulmonary resuscitation efforts performed by a medical or paramedical trained team. We considered both out-of-hospital and in-hospital settings, but undertook separate analyses, as patients in these settings are usually different with regard to causes of cardiac arrest and comorbidity. For our purposes, we defined cardiac arrest as sudden presentation of unresponsiveness, absence of spontaneous pulse, and absence of spontaneous respiration in a person not having a known or evident terminal disease.

Types of interventions

Intervention group

- Active chest compression-decompression using an appropriate device

Paramedical or medical teams participating in the study must have received specific training in ACDR CPR. Participants could receive STR by a witness (medical or not) until the arrival of the emergency team, but after that they must have received sustained ACDR CPR. We did not consider for inclusion trials alternating ACDR CPR and STR in the same participant.

Control group

- Standard manual chest compression by a trained paramedical or medical team, using the recommendations for cardiopulmonary resuscitation drawn up by the American Heart Association (American Heart Association 2005), the European

Resuscitation Council ([European Resuscitation Council 2005](#)), or both

Other interventions

Any intervention other than chest compression procedure, especially those interventions for basic and advanced life support, must have been applied equally in both intervention and control groups and should have been performed in accordance with the aforementioned recommendations. Time response from cardiac arrest to the beginning of resuscitation by the paramedical or medical team was assumed to be equal between treatment groups as a result of the randomisation procedure. If there were imbalances between the groups, this was dealt with by stratification or logistic regression analysis.

Types of outcome measures

Mortality

1. Immediate: participants not recovering spontaneous circulation in spite of resuscitation efforts.
2. To hospital discharge: participants not surviving long enough to be discharged from the hospital where they were first admitted.
3. Long-term: at three, six, or 12 months, or a combination of the aforementioned, when data were available.

Frequency of resultant neurological impairment in participants surviving until hospital discharge

This was classified as follows:

1. Moderate: impaired functionality or quality of life, but participant self-sufficient for basic needs of daily life. This corresponds to the Glasgow-Pittsburgh Cerebral Performance category 2 (moderate disability).
2. Severe: dependency for one or several basic needs of daily life. This corresponds to the Glasgow-Pittsburgh Cerebral Performance categories 3 and 4 (severe disability, vegetative state).
3. Any resultant neurologic impairment.

If data were available, we also assessed this outcome in the long-term (three, six, or 12 months, or a combination of the aforementioned).

Complications

1. Relevant complications derived from the applied technique.
2. Sternal and rib fractures.
3. Haemothorax or pneumothorax.
4. Internal organ damage.

We did not consider minor complications such as superficial trauma to the skin.

Search methods for identification of studies

Electronic searches

The following electronic databases were searched last on 14 January 2013:

1. the Cochrane Central Register of Controlled Trials (CENTRAL) in *The Cochrane Library*, Issue 12 of 12, December 2012;

2. MEDLINE on Ovid (1946 to January week 1 2013); and
3. EMBASE on Ovid (1980 to week 1 2013).

The search strategies employed can be found in [Appendix 1](#) (2008) and [Appendix 2](#) (2010 and 2013).

The RCT filters used for MEDLINE and EMBASE have been updated ([Lefebvre 2011](#)).

Searching other resources

We checked the reference list of all identified primary studies and review articles for other potential relevant citations. We contacted the sole company that manufactures ACDR CPR devices (Ambu International A/S) and colleagues working in the field of cardiopulmonary resuscitation for other published and unpublished studies. A search of the clinical trials registry [ClinicalTrials.gov](#) was conducted. There was no language restriction.

Data collection and analysis

Selection of studies

Two authors (CL-L, MM-B) selected trials for inclusion or exclusion after reading titles and abstracts of studies identified using the search strategy. We compared the selected trials and resolved any discrepancy by discussion and consensus. Using a predefined form, two authors independently read the full text of retained studies and included trials that met the above stated criteria. We checked the articles finally selected for the review to avoid including data published in duplicate.

Data extraction and management

Using a predefined form, two authors (CL-L, MM-B) independently extracted data. We checked the forms for agreement and decided differences by discussion and consensus. We extracted all data on the basis of intention-to-treat. When needed, we contacted authors of primary studies for additional information or data.

Assessment of risk of bias in included studies

Two authors (CL-L, MM-B) independently assessed the methodological quality of the selected studies, addressing adequacy of allocation concealment for randomised trials, which we ranked as yes (low risk of bias), unclear, or no (high risk of bias), following the *Cochrane Handbook for Systematic Reviews of Interventions* ([Higgins 2008](#); [Higgins 2011](#)). We resolved any differences of opinion by discussion and consensus.

Assessment of heterogeneity

We tested homogeneity between included studies using a fixed-effect or random-effects model, as appropriate. If significant heterogeneity was present, we attempted to explain the differences based on the clinical characteristics of the included studies. If a clinically dissimilar study existed, we did not combine it statistically.

Assessment of reporting biases

We carried out a funnel plot to test for the presence of publication bias, based on the data for the primary outcome of immediate mortality.

Data synthesis

We pooled trials using Review Manager 5 (RevMan) software and pooled relative risk calculated for all outcomes. If results for any outcome were significant, we also expressed them as number needed to treat (NNT) to prevent one adverse outcome.

Subgroup analysis and investigation of heterogeneity

We considered predefined subgroups for out-of-hospital studies. Personnel within the resuscitation teams were thought to have a possible effect on outcome because ACDR CPR requires more training than standard chest compression, and this could influence its performance. Therefore, we proposed subgroup analyses for studies where the resuscitation team included physicians and paramedics and for studies where resuscitation teams consisted of paramedics without a physician.

Sensitivity analysis

We performed sensitivity analyses by selectively pooling the following:

1. studies having the best methodological quality (allocation concealment adequate (A)); and
2. studies including the greatest number of participants (i.e. > 500 participants).

RESULTS

Description of studies

Results of the search

Our searches identified 231 references in total. We found 27 new publications for this update, of which we assessed two in detail, but none fulfilled our inclusion criteria.

We were aware of two additional controlled trials conducted in Brussels (Belgium) and Thessaloniki (Greece), which were cited as having contributed to the combined analysis of individual participant data performed by Mauer et al (Mauer 1999). However, this analysis offered no separate data from the individual trials. We were unable to obtain any published data and did not receive responses to our letters to the respective main authors.

After reading titles and abstracts, we retained 27 articles for detailed assessment. We excluded 10 articles reporting nine studies: five because they were not randomised (Arai 2001; Gueugniaud 1998; Lefrançois 1998; Panzer 1996; Rivers 1993); one because it included a large proportion of participants with pre-existing terminal disease (Cohen 1993); two because they combined ACDR CPR with other interventions not performed in controls (an inspiratory impedance threshold device in both cases) (Aufderheide 2011; Wolcke 2003); and one study (two references) because ACDR CPR was applied to all participant groups (Plaisance 2004). We present further details of the excluded studies in the 'Characteristics of excluded studies' section. One further article is a publication in Chinese, which is waiting for translation of the full text.

Finally, 16 articles reporting 10 studies fulfilled the defined inclusion criteria (Characteristics of included studies). Two of these studies included two separate trials respectively. Stiell reported on out-of-hospital and in-hospital participants separately (Stiell-

Inhospital 1996; Stiell-Prehospital 1996), and Schwab reported on groups of participants in two cities separately (Schwab-Fresno 1995; Schwab-S.Francisco 1995). Thus, we included 12 comparisons, cumulating a total of 4988 participants.

Included studies

Setting

Most trials (eight) included only out-of-hospital cardiac arrests; one included both out-of- and in-hospital cardiac arrests (Stiell-Prehospital 1996, n = 1011; Stiell-Inhospital 1996, n = 773), and one included only in-hospital participants (Tucker 1994, n = 53). The trials were conducted between 1993 and 1999 in Europe (France, Germany, Norway, United Kingdom) and North America (Canada, United States).

Stiell et al reported and analysed separately data from the two different settings of their trial: out-of-hospital and in-hospital participants. Schwab et al also reported and analysed separately data from the two cities where they conducted their study: Fresno and San Francisco (USA). We maintained the same pattern and pooled each of Stiell and Schwab's trials as two independent substudies.

Participants

All trials excluded people with a terminal disease or evidence of irreversible (i.e. brain) death. Most trials excluded also witnessed arrests, pregnant women, trauma victims, people in hypothermia, and intoxications. Three studies applied additional exclusion criteria: primary respiratory arrest, drowning, airway obstruction, and recent sternotomy.

The mean age of included participants was wide-ranging: between 65 and 71 years in eight studies, and lower in Goralski 1998 (61.5 years) and Plaisance 1999 (58.5 years). Two trials (Lurie 1994; Nolan 1998) stated that they could include young participants (> eight years old), but the mean age of the participants actually included was 67 years in both studies. Males predominated in all trials (57% to 73%) but one (Tucker 1994), where women represented 57%.

Five studies reported participant medical antecedents, presumed aetiology of the arrest, or both. Antecedents of heart disease (23% to 58%) and suspected cardiac aetiology (40% to 70%) were the most common conditions, followed by respiratory diseases (8% to 16%). Demographic and clinical characteristics were comparable between the ACDR CPR and STR groups in every trial.

Interventions

All trials compared ACDR CPR versus STR. In four of the out-of-hospital studies, the rescue teams comprised paramedics only; a physician directed the team in the remaining studies. In all the studies, paramedics and physicians were trained in ACDR CPR, receiving theoretical sessions and practicing with manikins. The frequency of retraining varied: every one month (Plaisance 1999), six months (Mauer 1996), or one year (Luiz 1996; Skogvoll 1999; Stiell-Inhospital 1996; Stiell-Prehospital 1996). Five studies did not state if retraining was provided (Goralski 1998; Lurie 1994; Nolan 1998; Schwab-Fresno 1995; Schwab-S.Francisco 1995; Tucker 1994).

Mean time from call to arrival of the rescue team ranged from 5.2 to 16 minutes in the out-of-hospital studies, depending on

geographic and emergency system characteristics. In the two in-hospital studies, mean response time was only 1.4 and 2 minutes. Mean adrenaline dose used varied from 2.7 mg to 14.3 mg in the different trials. Response times and adrenaline doses were not significantly different between ACDR CPR and STR groups in any individual trial.

Risk of bias in included studies

All included studies were randomised or quasi-randomised controlled trials. Allocation concealment was adequate (A) in four studies (Goralski 1998; Mauer 1996; Skogvoll 1999; Stiell-Inhospital 1996; Stiell-Prehospital 1996); unclear (B) in one (Luiz 1996); and clearly inadequate (C) in five (Lurie 1994; Nolan 1998; Plaisance 1999; Schwab-Fresno 1995; Schwab-S.Francisco 1995;

Tucker 1994), because they used alternating periods of time (the day, week, or month) to allocate participants and were therefore quasi-randomised designs.

No study was blinded to the intervention applied, as it is impossible to mask the use of the ACDR device. In four studies, authors conducted explicit intention-to-treat analysis. In the remaining six studies, we could extract - from the published data or after contacting authors - data as intention-to-treat. No outcome data were missing for the outcomes from each study that were pooled in the review. (Six of the studies did not report useable data on neurological outcomes.)

More details about the risk of bias are given in Figure 1 and Figure 2.

Figure 1. 'Risk of bias' graph: review authors' judgements about each 'Risk of bias' item presented as percentages across all included studies

Figure 2. 'Risk of bias' summary: review authors' judgements about each 'Risk of bias' item for each included study

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias): Mortality	Blinding of outcome assessment (detection bias): Neurological status
Goralski 1998	+	+	+	+	-	+	+
Luiz 1996	?	?	+	+	-	+	-
Lurie 1994	-	-	+	+	-	+	+
Mauer 1996	+	+	+	+	-	+	+
Nolan 1998	-	-	+	+	-	+	?
Plaisance 1999	-	-	+	+	-	+	+
Schwab-Fresno 1995	-	-	+	+	-	+	+
Schwab-S.Francisco 1995	-	-	+	+	-	+	?
Skogvoll 1999	+	+	+	+	-	+	?
Stiell-Inhospital 1996	+	+	+	+	-	+	+
Stiell-Prehospital 1996	+	+	+	+	-	+	+
Tucker 1994	-	-	+	+	-	+	?

Effects of interventions

There were few disagreements between the reviewers in selecting primary studies, assessing quality, or extracting data, and they were easily resolved by consensus. The funnel plot graphic was symmetrical, indicating that this test detected no publication bias or other bias.

We gave all results as pooled relative risk (RR) and its 95% confidence interval (CI) (ACDR CPR participants versus STR participants).

In-hospital studies

We found only two in-hospital studies fulfilling inclusion criteria ([Stiell-Inhospital 1996](#); [Tucker 1994](#)). The best was the Stiell study, a good-quality trial (A) that included 733 in-hospital participants.

This trial did not find any significant difference between ACDR CPR and STR groups neither in mortality, immediate (RR 1.01, 95% CI 0.91 to 1.12), or at hospital discharge (RR 1.01, 95% CI 0.96 to 1.06), nor in neurologic impairment in survivors (RR 1.14, 95% CI 0.46 to 2.87) or in complications (RR 0.97, 95% CI 0.49 to 1.93). The Tucker trial was a quality C study, with only 53 participants. No significant difference appeared in this study in any outcome either. Despite the differences in size and quality, the findings of the two in-hospital studies were similar.

Out-of-hospital studies

Mortality

All the out-of-hospital studies (cumulating 4162 participants) reported data for immediate mortality. Borderline heterogeneity between studies was found for this outcome (Chi² statistic = 14.81, df = 9, P = 0.10). This heterogeneity was largely due to [Plaisance 1999](#) and disappeared when we removed this study (Chi² statistic = 8.38, df = 8, P = 0.40). We found no effect of ACDR CPR on immediate mortality either using a random-effects model (RR 0.98, 95% CI 0.94 to 1.03) or a fixed-effect model (RR 0.98, 95% CI 0.94 to 1.01) or after removing [Plaisance 1999](#) (RR 1.00, 95% CI 0.96 to 1.04).

Eight trials (3412 participants) reported mortality at hospital discharge. They were homogeneous. We found no effect of ACDR CPR on mortality at hospital discharge (RR 0.99, 95% CI 0.98 to 1.01).

No study reported long-term mortality. [Plaisance 1999](#) followed for one year a specific subgroup of participants discharged without neurological damage, but the study did not follow up all the survivors of each treatment group. After contacting the author, further information about participants having neurological injury was not available.

Neurological outcome

Data on neurological outcome in survivors were available from five trials (cumulating 144 survivors) at hospital discharge. There was no heterogeneity between studies. Frequency of severe neurological damage showed a clear trend, without reaching statistical significance, being higher in the ACDR CPR group (RR 3.11, 95% CI 0.98 to 9.83), while moderate neurological damage did not differ between intervention groups (RR 0.98, 95% CI 0.34 to 2.79). The pooled relative risk of neurological impairment of any severity was 1.71 (95% CI 0.90 to 3.25). No study reported long-term neurological outcomes.

Complications

Six studies (3032 participants) provided data on complications related to treatment. Studies were homogenous. Relevant observed complications (rib or sternal fractures, pneumothorax or haemothorax, internal organ damage) were comparable with both resuscitation techniques (RR 1.09, 95% CI 0.86 to 1.38). Skin trauma or ecchymosis were more frequent with ACDR CPR in all studies.

Subgroup analysis (out-of-hospital studies only)

Results for mortality were unchanged when pooling separately trials with and without a physician in the first attending team. The trend toward more frequent neurological damage (of any severity) in the ACDR CPR group was apparent in those studies with only paramedics (RR 2.19, 95% CI 0.93 to 5.13) and disappeared when a physician directed the rescue team (RR 1.14, 95% CI 0.59 to 2.21).

However, there were few participants in each subgroup, and it was not possible to analyse neurological outcome by degree of severity given the number of participants.

Sensitivity analysis

All results were unchanged when selectively pooling the best-quality studies (adequate allocation concealment; four studies) or largest studies (those including > 500 participants: four studies).

DISCUSSION

Summary of main results

This systematic review found no evidence of benefit on mortality with the use of active compression-decompression cardiopulmonary resuscitation (ACDR CPR) compared with standard manual cardiopulmonary resuscitation (STR) for cardiopulmonary resuscitation. Confidence intervals were small with the trial evidence excluding a benefit greater than 6% relative risk reduction and a harm as big as 3% relative risk increase attributable to ACDR CPR.

With regard to neurologic outcome, a non-significant difference between treatment groups was observed in out-of-hospital studies, with the rate of neurologic impairment of severe degree and any severity tending to be higher in those treated with ACDR CPR. In subgroup analysis, this trend appeared in studies with attending teams comprising paramedics alone, and not in those with paramedics and physicians. However, this difference was not statistically significant, and the assessment of this outcome was limited: The number of participants with neurological impairment was small, assessors were often not blinded to the study intervention applied, and the Glasgow-Pittsburgh Cerebral Performance Scale is not a precise measure of neurologic function. Also, perceived differences between studies with and without physicians in rescue teams could merely reflect the overall numbers or rescuers attending the participant. These trials did not assess late neurological complications.

Complications were similar with both treatments. Some studies on autopsies of patients after unsuccessful resuscitation found more chest fractures, specifically sternal fractures, with ACDR CPR than with STR, and also a higher risk of iatrogenic cardiac injury ([Baubin 1999](#); [Rabl 1996](#)). The clinical trials included in this review were not specifically designed to study complications. Nevertheless, in several of them, autopsies were done in a number of non-survivors ([Stiell-Inhospital 1996](#); [Schwab-Fresno 1995](#); [Tucker 1994](#)). In all the studies included in this review and in the pooled results, the observed complications were very similar with both techniques, with the exception of skin trauma or ecchymosis, which were more frequent with ACDR CPR.

Potential biases in the review process

The objective of this systematic review was to assess the overall effectiveness of ACDR CPR in the wide spectrum of clinical practice. A possible limitation of this approach is to pool together trials conducted in different clinical conditions and emergency medical systems. Percentage of participants in ventricular fibrillation, time to receive life support, composition, and training of medical teams are all factors that varied from study to study. Possible benefits of ACDR CPR, or conversely potential dangers, in specific subgroups

of people or specific emergency medical systems might have been missed by being diluted in the global pool.

However, results seem to be consistent. Combining the included studies in different ways, by size, quality, team composition, and setting, did not change the main findings. Also, statistically significant heterogeneity between studies was not found, with the only exception of one outcome, immediate mortality, due to one study (Plaisance 1999). Neither the exclusion nor the inclusion (using both fixed- and random-effects models for statistics) of this study modified the results.

Plaisance 1999 showed better results for immediate mortality than the other trials. This difference could be explained by several reasons. It could be due to a bias in participant selection, as allocation concealment was clearly inadequate. But it could be due also to a better performance of the ACDR CPR technique. In this study, practitioners were experienced in ACDR CPR, and frequent retraining was performed, with rapid rotation of staff to avoid fatigue and conduct of the entire cardiopulmonary resuscitation at the scene of cardiac arrest directed by a physician. It was not possible to compare the outcomes of this study with the other included trials, other than immediate mortality, because not all the participants were assessed until hospital discharge. Participants were followed to discharge only if they had no neurological impairment.

Agreements and disagreements with other studies or reviews

Our results are different from the meta-analysis by Mauer 1999 with regard to immediate mortality, where they found a significant reduction (odds ratio 0.83, 95% CI 0.695 to 0.99). The main difference seems to be that we pooled more studies than Mauer: the studies by Schwab, Goralski, and Skogvoll, leading to 1296 more participants. All these trials had negative results for ACDR CPR. Mauer et al used individual participant data and analysed one-hour mortality while we recorded the immediate mortality as defined by authors of each trial, usually in the first minutes after resuscitation. However, the differences are limited to results for early mortality; Mauer and colleagues found no significant difference in mortality at hospital discharge neither.

Other considerations

Difficulty in applying optimal ACDR CPR in clinical settings, reported by several studies, reveal that this procedure, while seemingly relatively simple, is in fact much more complex than STR. This complexity could limit its effectiveness in real practice. In studies on transducer-equipped manikins, ACDR CPR required a higher physical effort than STR (Shultz 1995). Staff fatigue led to a significant reduction of compression rate and depth, as well as decompression force, after only two minutes in one study (Skogvoll 1997). ACDR CPR mechanical performance was also worse than STR during patient transport (Sunde 1997). In some of the clinical trials included in this review, they had limited available personnel to sustain chest massage, chest massage was performed during transport, or both (Nolan 1998; Schwab-Fresno 1995; Schwab-S.Francisco 1995; Stiell-Prehospital 1996).

The 2010 American Heart Association guidelines for cardiopulmonary resuscitation increased the focus on adequate chest compression as a critical component of high-

quality cardiopulmonary resuscitation, specifically in minimising interruptions in chest compressions, providing compressions of adequate rate and depth, and avoiding leaning between compressions (American Heart Association 2010). The difficulty of applying ACDR CPR during transport and the reduced performance of ACDR CPR observed in some trials because of early fatigue may hinder in real practice the theoretical advantages of ACDR CPR over manual compression.

One additional problem, non-adherence to chest of the ACDR CPR device, was common. This defect was found in a variable proportion of participants, which ranged from 9% (Lurie 1994; Mauer 1996; Nolan 1998) to 16% (Goralski 1998; Luiz 1996; Stiell-Inhospital 1996; Stiell-Prehospital 1996), but was as high as 24% in one study (Skogvoll 1999). In most of those participants, staff were unable to continue ACDR CPR and performed STR in substitution.

There are several important determinants of survival following cardiac arrest that are independent of the technique used. Time from arrest to basic and advanced life support, specially to defibrillation, is a well-characterised major factor (Eisenberg 1979; Mullie 1989), most important in out-of-hospital arrests (Becker 1991; Nichol 1996). Other major factors influencing survival are patient-intrinsic: primary cause of arrest, initial heart rhythm (Pepe 1993; Zoch 2000), coexisting diseases, and age (de Vos 1999; Ebell 1992).

Most experimental studies concluded that ACDR CPR, compared to STR, improved haemodynamics during cardiopulmonary resuscitation. Despite this physiological advantage, this does not appear to be sufficient to modify the natural evolution of cardiac arrest.

AUTHORS' CONCLUSIONS

Implications for practice

There is no clear evidence of benefits from the use of active compression-decompression compared to standard manual chest compression in people with cardiac arrest occurring in different settings and different emergency medical systems. In the light of these results, ACDR CPR may not have a place in routine clinical practice. If performed, it should be by a well-trained, regularly re-trained team and ideally in the context of controlled clinical trials.

Implications for research

It is possible that changes in the design of the ACDR CPR device, particularly to improve adherence to the chest wall, could make it more efficient in practice. Combination of ACDR CPR with other devices designed to further increase negative intrathoracic pressures, e.g. an impedance threshold device, might improve the effectiveness of ACDR CPR. A large randomised controlled trial has found a significant increase in short- and long-term survival with the combination of ACDR CPR combined with augmented negative intrathoracic pressure via an impedance threshold device (Aufderheide 2011). Ideally, other studies should confirm these results.

In new clinical trials studying ACDR CPR, special attention to complications would be desirable, as well as long-term follow up of neurological outcomes.

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REFERENCES

References to studies included in this review

Goralski 1998 {published data only}

- * Goralski M, Villéger JL, Cami G, Linassier P, Guilles-des-Buttes P, Fabbri P, et al. Evaluation of active compression-decompression cardiopulmonary resuscitation in out-of-hospital cardiac arrest [Évaluation de la compression décompression active dans la réanimation de l'arrêt cardiaque extrahospitalier]. *Réan Urg* 1998;**7**:543-50. [EMBASE: 1999119791]

Villegier JL, Linassier P, Skrobala D, Goralski M. Active compression decompression resuscitation in out-of-hospital cardiac arrest: preliminary results. Abstract: European Society of Anaesthesiologists Annual Congress Abstracts. Queen Elizabeth II Conference Centre, London. 1-5 June, 1996. *British Journal of Anaesthesia* 1996;**76**(Suppl 2):115-6. [PUBMED: 8679383]

Luiz 1996 {published data only}

Ellinger K, Luiz T, Denz C, van Ackern K. Randomized use of an active compression-decompression technique within the scope of preclinical resuscitation [Randomisierte Anwendung der aktiven Kompressions-Dekompressions-Technik (ACD) im Rahmen der präklinischen Reanimation]. *Anästhesiologie, Intensivmedizin, Notfallmedizin, Schmerztherapie: AINS* 1994;**29**(8):492-500. [MEDLINE: 95143358]

- * Luiz T, Ellinger K, Denz C. Active compression-decompression cardiopulmonary resuscitation does not improve survival in patients with prehospital cardiac arrest in a physician-manned emergency medical system. *Journal of Cardiothoracic and Vascular Anesthesia* 1996;**10**(2):178-86. [MEDLINE: 97003055]

Lurie 1994 {published data only}

Lurie KG, Shultz JJ, Callahan ML, Schwab TM, Gisch T, Rector T, et al. Evaluation of active compression-decompression CPR in victims of out-of-hospital cardiac arrest. *JAMA* 1994;**271**(18):1405-11. [MEDLINE: 94231638]

Mauer 1996 {published data only}

Mauer D, Schneider T, Dick W, Elich D, Mauer M. Active compression-decompression resuscitation. Improved survival rate in an emergency medicine system with emergency physician assistance? [Aktive Kompressions- Dekompressions-Reanimation (ACD-CPR). Verbesserte Überlebensraten in einem notarztgestützten Rettungssystem?]. *Medizinische Klinik* 1997;**92**(7):381-8. [MEDLINE: 97405441]

- * Mauer D, Schneider T, Dick W, Withelm A, Elich D, Mauer M. Active compression-decompression resuscitation: a prospective, randomized study in a two-tiered EMS system with physicians in the field. *Resuscitation* 1996;**33**(2):125-34. [MEDLINE: 97177615]

Mauer D, Schneider T, Elich D, Dick W. Carbon dioxide levels during pre-hospital active compression-decompression versus standard cardiopulmonary resuscitation. *Resuscitation* 1998;**39**(1-2):67-74. [MEDLINE: 9918450]

Nolan 1998 {published data only}

Nolan J, Smith G, Evans R, McCusker K, Lubas P, Parr M, et al. The United Kingdom pre-hospital study of active compression-decompression resuscitation. *Resuscitation* 1998;**37**(2):119-25. [MEDLINE: 1998334162]

Plaisance 1999 {published and unpublished data}

Plaisance P, Adnet F, Vicaut E, Hennequin B, Magne P, Prudhomme C, et al. Benefit of active compression-decompression cardiopulmonary resuscitation as a prehospital advanced cardiac life support: a randomized multicenter study. *Circulation* 1997;**95**(4):955-61. [MEDLINE: 97207464]

- * Plaisance P, Lurie KG, Vicaut E, Adnet F, Petit JL, Epain D, et al. A comparison of standard cardiopulmonary resuscitation and active compression-decompression resuscitation for out-of-hospital cardiac arrest. *New England Journal of Medicine* 1999;**341**(8):569-75. [MEDLINE: 1999362123]

Schwab-Fresno 1995 {published data only}

Callahan ML, Schwab TM, Shultz JJ, Utech TA, Madsen CD, Gist T, et al. A randomized prospective trial of active compression-decompression CPR in prehospital cardiac arrest (abstract). *Annals of Emergency Medicine* 1993;**22**:174.

- * Schwab TM, Callahan ML, Madsen CD, Utecht TA. A randomized clinical trial of active compression-decompression CPR vs standard CPR in out-of-hospital cardiac arrest in two cities. *JAMA* 1995;**273**(16):1261-8. [MEDLINE: 95230849]

Schwab-S.Francisco 1995 {published data only}

Callahan ML, Schwab TM, Shultz JJ, Utech TA, Madsen CD, Gist T, et al. A randomized prospective trial of active compression-decompression CPR in prehospital cardiac arrest (abstract). *Annals of Emergency Medicine* 1993;**22**:174.

- * Schwab TM, Callahan ML, Madsen CD, Utecht TA. A randomized clinical trial of active compression-decompression CPR vs standard CPR in out-of-hospital cardiac arrest in two cities. *JAMA* 1995; Vol. 273, issue 16:1261-8.

Skogvoll 1999 {published and unpublished data}

Skogvoll E, Wik L. Active compression-decompression cardiopulmonary resuscitation: a population-based, prospective randomised clinical trial in out-of-hospital cardiac arrest. *Resuscitation* 1999;**42**(3):163-72. [MEDLINE: 20088494]

Stiell-Inhospital 1996 {published data only}

Stiell IG, Hébert PC, Wells GA, Laupacis A, Vandemheen K, Dreyer JF, et al. The Ontario trial of active compression-decompression cardiopulmonary resuscitation for in-hospital and prehospital cardiac arrest. *JAMA* 1996;**275**(18):1417-23. [MEDLINE: 96210341]

Stiell-Prehospital 1996 {published data only}

Stiell IG, Hébert PC, Wells GA, Laupacis A, Vandemheen K, Dreyer JF, et al. The Ontario trial of active compression-decompression cardiopulmonary resuscitation for in-hospital and prehospital cardiac arrest. *JAMA* 1996; Vol. 275, issue 18:1417-23. [MEDLINE: 96210341]

Tucker 1994 {published data only}

Tucker KJ, Galli F, Savitt MA, Kahsai D, Bresnahan L, Redberg RF. Active compression-decompression resuscitation: effect on resuscitation success after in-hospital cardiac arrest. *Journal of the American College of Cardiology* 1994;**24**(1):201-9. [MEDLINE: 94274985]

References to studies excluded from this review
Arai 2001 {published data only}

Arai T, Adachi N, Tabo E, Yorozya T, Nagaro T, Ochi G, et al. Evaluation of efficiency of ACD-CPR and STD-CPR: a multi-institutional study [Japanese]. *Masui. The Japanese Journal of Anesthesiology* 2001;**50**(3):307-15. [PUBMED: 14568898]

Aufderheide 2011 {published data only}

Aufderheide TP, Frascone RJ, Wayne MA, Mahoney BD, Swor RA, Domeier RM, et al. Standard cardiopulmonary resuscitation versus active compression-decompression cardiopulmonary resuscitation with augmentation of negative intrathoracic pressure for out-of-hospital cardiac arrest: a randomised trial. *Lancet* 2011;**377**(9762):301-11. [DOI: [10.1016/S0140-6736\(10\)62103-4](https://doi.org/10.1016/S0140-6736(10)62103-4); PUBMED: 21251705]

Cohen 1993 {published data only}

Cohen TJ, Goldner BG, Maccaro PC, Ardito AP, Trazzera S, Cohen MB, et al. A comparison of active compression-decompression cardiopulmonary resuscitation with standard cardiopulmonary resuscitation for cardiac arrests occurring in the hospital. *New England Journal of Medicine* 1993;**329**(26):1918-21. [MEDLINE: 94067237]

Gueugniaud 1998 {published data only}

Gueugniaud PY, Mols P, Goldstein P, Pham E, Dubien PY, Deweerdt C, et al. A comparison of repeated high doses and repeated standard doses of epinephrine for cardiac arrest outside the hospital. European Epinephrine Study Group. *New England Journal of Medicine* 1998;**339**(22):1595-601. [MEDLINE: 99032032]

Lefrançois 1998 {published data only}

Lefrançois D. Prehospital use of ACD-CPR in a EMT-D level EMS system (abstract). *Resuscitation* 1998;**37**(2):S31.

Panzer 1996 {published data only}

Panzer W, Bretthauer M, Klingler H, Bahr J, Rathgeber J, Kettler D. ACD versus standard CPR in a prehospital setting. *Resuscitation* 1996;**33**(2):117-24. [MEDLINE: 97177614]

Plaisance 2004 {published data only}

Plaisance P, Lurie KG, Payen D. Inspiratory impedance during active compression-decompression cardiopulmonary resuscitation: a randomized evaluation in patients in cardiac arrest. *Circulation* 2000;**101**(9):989-94. [PUBMED: 10704165]

* Plaisance P, Lurie KG, Vicaut E, Martin D, Gueugniaud PY, Petit JL, et al. Evaluation of an impedance threshold device in patients receiving active compression-decompression cardiopulmonary resuscitation for out of hospital cardiac arrest. *Resuscitation* 2004;**61**(3):265-71. [PUBMED: 15172704]

Rivers 1993 {published data only}

Rivers E, Boczar ME, Smithline HA, Lurie KJ, Nowak RM. A comparison of mechanical, standard and active compression-decompression CPR in out-of-hospital cardiac arrest patients (abstract). *Circulation* 1993;**88**:I-193.

Wolcke 2003 {published data only}

Wolcke BB, Mauer DK, Schoefmann MF, Teichmann H, Provo TA, Lindner KH, et al. Comparison of standard cardiopulmonary resuscitation versus the combination of active compression-decompression cardiopulmonary resuscitation and an inspiratory impedance threshold device for out-of-hospital cardiac arrest. *Circulation* 2003;**108**(18):2201-5. [PUBMED: 14568898]

References to studies awaiting assessment
He 2003 {published data only}

He Q, Wan Z, Wang L. Random control trial of the efficacy of cardio pump on pre-hospital cardiac arrest [Article in Chinese]. *Zhongguo Wei Zhong Bing Ji Jiu Yi Xue* 2003 May;**15**(5):292-4. [PUBMED: 12837190]

Additional references
American Heart Association 2005

International Liaison Committee on Resuscitation. 2005 International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science with Treatment Recommendations. Part 2: Adult basic life support. *Circulation* 2005;**112**(22 Suppl):III5-III16.

American Heart Association 2010

Field JM, Hazinski MF, Sayre MR, Chameides L, Schexnayder SM, Hemphill R, et al. Part 1: executive summary: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* 2010;**122**(18 Suppl 3):S640-56. [DOI: [10.1161/CIRCULATIONAHA.110.970889](https://doi.org/10.1161/CIRCULATIONAHA.110.970889); PUBMED: 20956217]

Baubin 1999

Baubin M, Sumann G, Rabl W, Eibl G, Wenzel V, Mair P. Increased frequency of thorax injuries with ACD-CPR. *Resuscitation* 1999;**41**(1):33-8. [MEDLINE: 99387346]

Becker 1991

Becker LB, Ostrander MP, Barrett J, Kondos GT. Outcome of CPR in a large metropolitan area - where are the survivors?. *Annals of Emergency Medicine* 1991;**20**(4):355-61. [MEDLINE: 91166102]

Brooks 2011

Brooks SC, Bigham BL, Morrison LJ. Mechanical versus manual chest compressions for cardiac arrest. *Cochrane Database of Systematic Reviews* 2011, Issue 1. [DOI: [10.1002/14651858.CD007260.pub2](https://doi.org/10.1002/14651858.CD007260.pub2)]

Cohen 1992

Cohen TJ, Tucker KJ, Lurie KG, Redberg RF, Dutton JP, Dwyer KA, et al. Active compression-decompression. A new method of cardiopulmonary resuscitation. *Cardiopulmonary Resuscitation*

Working Group. *JAMA* 1992;**267**(21):2916-23. [MEDLINE: 92260705]

de Vos 1999

de Vos R, Koster RW, De Haan RJ, Oosting H, van der Wouw PA, Lampe-Schoenmaeckers AJ. In-hospital cardiopulmonary resuscitation: prearrest morbidity and outcome. *Archives of Internal Medicine* 1999;**159**(8):845-50. [MEDLINE: 99235336]

Ebell 1992

Ebell MH. Prearrest predictors of survival following in-hospital cardiopulmonary resuscitation: a meta-analysis. *Journal of Family Practice* 1992;**34**(5):551-8. [MEDLINE: 92251314]

Eisenberg 1979

Eisenberg MS, Bergner L, Hallstrom A. Cardiac resuscitation in the community. Importance of rapid provision and implications for program planning. *JAMA* 1979;**241**(18):1905-7. [MEDLINE: 79154439]

European Resuscitation Council 2005

Handley AJ, Koster R, Monsieurs K, Perkins GD, Davies S, Bossaert L, European Resuscitation Council. European Resuscitation Council guidelines for resuscitation 2005. Section 2. Adult basic life support and use of automated external defibrillators. *Resuscitation* 2005;**67**(Suppl 1):S7-S23. [MEDLINE: 16321717]

Higgins 2008

Higgins JPT, Altman DG, Sterne JAC (editors). Chapter 8: Assessing risk of bias in included studies. In: Higgins JPT, Green S (editors). *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.0.0 [updated February 2008]. The Cochrane Collaboration, 2008. Available from www.cochrane-handbook.org.

Higgins 2011

Higgins JPT, Green S. *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0 [updated March 2011]. The Cochrane Collaboration, 2011. Available from www.cochrane-handbook.org.

Lefebvre 2011

Lefebvre C, Manheimer E, Glanville J. Chapter 6: Searching for studies. In: Higgins JPT, Green S (editors). *Cochrane Handbook for Systematic Reviews of Interventions* Version 5.1.0 [updated March 2011]. The Cochrane Collaboration, 2011. Available from www.cochrane-handbook.org.

Malzer 1996

Malzer R, Zeiner A, Binder M, Domanovits H, Knappitsch G, Sterz F, et al. Hemodynamic effects of active compression-decompression after prolonged CPR. *Resuscitation* 1996;**31**(3):243-53. [MEDLINE: 96377570]

Mauer 1999

Mauer DK, Nolan J, Plaisance P, Sitter H, Benoit H, Stiell IG, et al. Effect of active compression-decompression resuscitation (ACD-CPR) on survival: a combined analysis using individual patient data. *Resuscitation* 1999;**41**(3):249-56. [MEDLINE: 99435567]

Mullie 1989

Mullie A, Van Hoeyweghen R, Quets A. Influence of time intervals on outcome of CPR. The Cerebral Resuscitation Study Group. *Resuscitation* 1989;**17** Suppl:S23-33. [MEDLINE: 89387923]

Nichol 1996

Nichol G, Detsky AS, Stiell IG, O'Rourke K, Wells G, Laupacis A. Effectiveness of emergency medical services for victims of out-of-hospital cardiac arrest: a metaanalysis. *Annals of Emergency Medicine* 1996;**27**(6):700-10. [MEDLINE: 96240168]

Orliaguet 1995

Orliaguet GA, Carli PA, Rozenberg A, Janniere D, Sauval P, Delpech P. End-tidal carbon dioxide during out-of-hospital cardiac arrest resuscitation: comparison of active compression-decompression and standard CPR. *Annals of Emergency Medicine* 1995;**25**(1):48-51. [MEDLINE: 95100647]

Pepe 1993

Pepe PE, Levine RL, Fromm RE Jr, Curka PA, Clark PS, Zachariah BS. Cardiac arrest presenting with rhythms other than ventricular fibrillation: contribution of resuscitative efforts toward total survivorship. *Critical Care Medicine* 1993;**21**(12):1838-43. [MEDLINE: 94074325]

Rabl 1996

Rabl W, Baubin M, Broinger G, Scheithauer R. Serious complications from active compression-decompression cardiopulmonary resuscitation. *International Journal of Legal Medicine* 1996;**109**(2):84-9. [MEDLINE: 97068865]

Schwab 1995

Schwab TM, Callahan ML, Madsen CD, Utecht TA. A randomized clinical trial of active compression-decompression CPR vs standard CPR in out-of-hospital cardiac arrest in two cities. *JAMA* 1995;**273**(16):1261-8. [MEDLINE: 95230849]

Shultz 1994

Shultz JJ, Coffeen P, Sweeney M, Detloff B, Kehler C, Pineda E, et al. Evaluation of standard and active compression-decompression CPR in an acute human model of ventricular fibrillation. *Circulation* 1994;**89**(2):684-93. [MEDLINE: 94147601]

Shultz 1995

Shultz JJ, Mianulli MJ, Gisch TM, Coffeen PR, Haidet GC, Lurie KG. Comparison of exertion required to perform standard and active compression-decompression cardiopulmonary resuscitation. *Resuscitation* 1995;**29**(1):23-31. [MEDLINE: 95304190]

Skogvoll 1997

Skogvoll E, Wik L. Active compression-decompression cardiopulmonary resuscitation (ACD-CPR) compared with standard CPR in a manikin model--decompression force, compression rate, depth and duration. *Resuscitation* 1997;**34**(1):11-6. [MEDLINE: 97204246]

Stiell 1996

Stiell IG, Hébert PC, Wells GA, Laupacis A, Vandemheen K, Dreyer JF, et al. The Ontario trial of active compression-decompression cardiopulmonary resuscitation for in-hospital

and prehospital cardiac arrest. *JAMA* 1996;**275**(18):1417-23. [MEDLINE: 96210341]

Sunde 1997

Sunde K, Wik L, Steen PA. Quality of mechanical, manual standard and active compression-decompression CPR on the arrest site and during transport in a manikin model. *Resuscitation* 1997;**34**(3):235-42. [MEDLINE: 97321676]

Tucker 1993

Tucker KJ, Redberg RF, Schiller NB, Cohen TJ. Active compression-decompression resuscitation: analysis of transmitral flow and left ventricular volume by transesophageal

echocardiography in humans. Cardiopulmonary Resuscitation Working Group. *Journal of the American College of Cardiology* 1993;**22**(5):1485-93. [MEDLINE: 94044260]

Zoch 2000

Zoch TW, Desbiens NA, DeStefano F, Stueland DT, Layde PM. Short- and long-term survival after cardiopulmonary resuscitation. *Archives of Internal Medicine* 2000;**160**(13):1969-73. [MEDLINE: 20347643]

* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES

Characteristics of included studies [ordered by study ID]

Goralski 1998

Methods	Randomised controlled trial
Participants	n = 150 Mean age: 61.5 years Male: 72% Exclusions: trauma victims VF: 15% Cardiac cause of heart arrest: 70%
Interventions	ACDR vs STR Physician in responder team Mean response time: 16 minutes Mean adrenaline dose: 12.5 mg
Outcomes	• Immediate and at-hospital discharge mortality
Notes	Prehospital Orleans, Tours (France) 1995 to 1996

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	

Goralski 1998 (Continued)

Selective reporting (reporting bias)	Low risk
Blinding of participants and personnel (performance bias) All outcomes	High risk
Blinding of outcome assessment (detection bias) Mortality	Low risk
Blinding of outcome assessment (detection bias) Neurological status	Low risk

Luiz 1996

Methods	Randomised controlled trial
Participants	n = 61 Mean age: 69 years Male: 73% Exclusions: pregnancy, trauma victims VF: 27% Cardiac antecedents: 52% Pulmonary antecedents: 12.5%
Interventions	ACDR vs STR Physician in responder team Mean response time: 8 minutes Adrenaline dose: ?
Outcomes	<ul style="list-style-type: none"> • Immediate and at-hospital discharge mortality • Neurological outcome • Complications
Notes	Prehospital Mannheim (Germany) 1993

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Unclear risk	Participants "were randomised according to a schedule". No more information was available

Luiz 1996 (Continued)

Allocation concealment (selection bias)	Unclear risk	No information about how the randomisation schedule was applied
Incomplete outcome data (attrition bias) All outcomes	Low risk	No missing outcome data
Selective reporting (reporting bias)	Low risk	All outcomes analysed in the review had been reported adequately
Blinding of participants and personnel (performance bias) All outcomes	High risk	Blinding of intervention (use of ACDR device) was not possible
Blinding of outcome assessment (detection bias) Mortality	Low risk	Assessment was not blind, but we did not believe this introduced bias as death is a hard criteria, rarely misattributed
Blinding of outcome assessment (detection bias) Neurological status	High risk	No blinding; we thought the outcome measurement was likely to have been influenced by lack of blinding

Lurie 1994

Methods	Randomised controlled trial
Participants	n = 130 Mean age: 67 years Male: 72% Exclusions: hypothermia, trauma victims VF: 62% Cardiac antecedents: 62%
Interventions	ACDR vs STR Only paramedics in responder team Mean response time: 5.2 minutes Mean adrenaline dose: 2.7 mg
Outcomes	<ul style="list-style-type: none"> Immediate and at-hospital discharge mortality Complications
Notes	Prehospital St.Paul (USA) 1992 to 1993

Risk of bias

Bias	Authors' judgement	Support for judgement
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Lurie 1994 (Continued)

Random sequence generation (selection bias)	High risk
Allocation concealment (selection bias)	High risk
Incomplete outcome data (attrition bias) All outcomes	Low risk
Selective reporting (reporting bias)	Low risk
Blinding of participants and personnel (performance bias) All outcomes	High risk
Blinding of outcome assessment (detection bias) Mortality	Low risk
Blinding of outcome assessment (detection bias) Neurological status	Low risk

Mauer 1996

Methods	Randomised controlled trial
Participants	n = 220 Mean age: 68.7 years Male: ? Exclusions: pregnancy, hypothermia, drowning, overdose, trauma victims VF: 45% Cardiac antecedents: 61% Pulmonary antecedents: 12.7%
Interventions	ACDR vs STR Physician in responder team Mean response time: 9 minutes Mean adrenaline dose: 4.3 mg
Outcomes	<ul style="list-style-type: none"> Immediate and at-hospital discharge mortality Complications
Notes	Prehospital Mainz (Germany) 1992 to 1995

Mauer 1996 (Continued)

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Centralised randomisation list
Allocation concealment (selection bias)	Low risk	24-hour centralised randomisation
Incomplete outcome data (attrition bias) All outcomes	Low risk	No missing outcome data
Selective reporting (reporting bias)	Low risk	All outcomes analysed in the review had been reported adequately
Blinding of participants and personnel (performance bias) All outcomes	High risk	Blinding of intervention (use of ACDR device) was not possible
Blinding of outcome assessment (detection bias) Mortality	Low risk	Assessment was not blind, but we did not believe this introduced bias as death is a hard criteria, rarely misattributed
Blinding of outcome assessment (detection bias) Neurological status	Low risk	Neurological outcome was not studied in this trial

Nolan 1998

Methods	Randomised controlled trial
Participants	n = 674 Mean age: 67 years Male: 68% Exclusions: trauma victims VF: 60%
Interventions	ACDR vs STR Only paramedics in responder team Mean response time: 8.7 minutes Adrenaline dose: ?
Outcomes	<ul style="list-style-type: none"> Immediate and at-hospital discharge mortality Neurological outcome Complications
Notes	Prehospital

Nolan 1998 (Continued)

Cardiff, Portsmouth, Bristol (UK)
1994 to 1995

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Interventions were alternated every 2 months
Allocation concealment (selection bias)	High risk	Alternation
Incomplete outcome data (attrition bias) All outcomes	Low risk	No missing outcome data
Selective reporting (reporting bias)	Low risk	All outcomes analysed in the review had been reported adequately
Blinding of participants and personnel (performance bias) All outcomes	High risk	Blinding of intervention (use of ACDR device) was not possible
Blinding of outcome assessment (detection bias) Mortality	Low risk	Assessment was not blind, but we did not believe this introduced bias as death is a hard criteria, rarely misattributed
Blinding of outcome assessment (detection bias) Neurological status	Unclear risk	No information was given about how neurological outcome was assessed

Plaisance 1999

Methods	Randomised controlled trial
Participants	<p>n = 750</p> <p>Mean age: 58.5 years</p> <p>Male: 68%</p> <p>Exclusions: irreversible death, excessive delay</p> <p>VF: 12%</p> <p>Cardiac cause of heart arrest: 64%</p>
Interventions	<p>ACDR vs STR</p> <p>Physician in responder team</p> <p>Mean response time: 9.2 minutes</p> <p>Mean adrenaline dose: 14.3 mg</p>
Outcomes	<ul style="list-style-type: none"> Immediate mortality Complications

Plaisance 1999 (Continued)

Intention-to-treat analysis was explicitly done

Notes	Prehospital Paris (France) 1993 to 1995
Risk of bias	
Bias	Authors' judgement Support for judgement
Random sequence generation (selection bias)	High risk
Allocation concealment (selection bias)	High risk
Incomplete outcome data (attrition bias) All outcomes	Low risk
Selective reporting (reporting bias)	Low risk
Blinding of participants and personnel (performance bias) All outcomes	High risk
Blinding of outcome assessment (detection bias) Mortality	Low risk
Blinding of outcome assessment (detection bias) Neurological status	Low risk

Schwab-Fresno 1995

Methods	Randomised controlled trial
Participants	n = 253 Mean age: 65 years Male: 61% Exclusions: trauma victims, hypothermia VF: 38%
Interventions	ACDR vs STR Only paramedics in responder team Mean response time: 5.3 minutes Adrenaline dose: ?

Schwab-Fresno 1995 (Continued)

Outcomes	<ul style="list-style-type: none"> • Immediate and at-hospital discharge mortality • Complications
Notes	Prehospital Fresno (USA) 1992 to 1993

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	The method of CPR was alternated on a weekly basis
Allocation concealment (selection bias)	High risk	Alternation
Incomplete outcome data (attrition bias) All outcomes	Low risk	No missing outcome data
Selective reporting (reporting bias)	Low risk	All outcomes analysed in the review had been reported adequately
Blinding of participants and personnel (performance bias) All outcomes	High risk	Blinding of intervention (use of ACDR device) was not possible
Blinding of outcome assessment (detection bias) Mortality	Low risk	Assessment was not blind, but we did not believe this introduced bias as death is a hard criteria, rarely misattributed
Blinding of outcome assessment (detection bias) Neurological status	Low risk	Neurological outcome was not studied in this trial

Schwab-S.Francisco 1995

Methods	Randomised controlled trial
Participants	n = 607 Mean age: 65 years Male: 67% Exclusions: trauma victims, hypothermia VF: 18%
Interventions	ACDR vs STR Mean response time: 5.5 minutes Adrenaline dose: ?
Outcomes	<ul style="list-style-type: none"> • Immediate and at-hospital discharge mortality

Schwab-S.Francisco 1995 (Continued)

- Complications

Notes	Prehospital San Francisco (USA) 1992 to 1993	
<i>Risk of bias</i>		
Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	Half the fire stations responding to emergency calls were randomised to ACDR CPR for the entire duration of the study
Allocation concealment (selection bias)	High risk	Open allocation
Incomplete outcome data (attrition bias) All outcomes	Low risk	No missing outcome data
Selective reporting (reporting bias)	Low risk	All outcomes analysed in the review had been reported adequately
Blinding of participants and personnel (performance bias) All outcomes	High risk	Blinding of intervention (use of ACDR device) was not possible
Blinding of outcome assessment (detection bias) Mortality	Low risk	Assessment was not blind, but we did not believe this introduced bias as death is a hard criteria, rarely misattributed
Blinding of outcome assessment (detection bias) Neurological status	Unclear risk	Neurological outcome was not studied in this trial

Skogvoll 1999

Methods	Randomised controlled trial
Participants	n = 306 Mean age: 71 years Male: 73% Exclusions: trauma victims, intoxication, airway obstruction VF: 57%
Interventions	ACDR vs STR Physician in responder team Mean response time: 9 minutes Adrenaline dose: ?

Skogvoll 1999 (Continued)

Outcomes	<ul style="list-style-type: none"> • Immediate and at-hospital discharge mortality • Neurological outcome <p>Intention-to-treat analysis was explicitly done</p>
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Notes	Prehospital Trondheim (Norway) 1994 to 1998
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Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	Random number table
Allocation concealment (selection bias)	Low risk	Sequentially numbered, opaque sealed envelopes
Incomplete outcome data (attrition bias) All outcomes	Low risk	No missing outcome data
Selective reporting (reporting bias)	Low risk	All outcomes analysed in the review had been reported adequately
Blinding of participants and personnel (performance bias) All outcomes	High risk	Blinding of intervention (use of ACDR device) was not possible
Blinding of outcome assessment (detection bias) Mortality	Low risk	Assessment was not blind, but we did not believe this introduced bias as death is a hard criteria, rarely misattributed
Blinding of outcome assessment (detection bias) Neurological status	Unclear risk	No information is given about who assessed neurological outcome and how

Stiell-Inhospital 1996

Methods	Randomised controlled trial
Participants	<p>n = 773</p> <p>Mean age: 68.5 years</p> <p>Male: 57%</p> <p>Exclusions: trauma, recent sternotomy, operating room</p> <p>VF: 32%</p> <p>Cardiac antecedents: 49%</p> <p>Cardiac cause of heart arrest: 77%</p>

Stiell-Inhospital 1996 (Continued)

Respiratory cause: 16%

Interventions	ACDR vs STR Physician in responder team Mean response time: 1.4 minutes Adrenaline dose: ?
Outcomes	<ul style="list-style-type: none"> • Immediate and at-hospital discharge mortality • Neurological outcome • Complications Intention-to-treat analysis was explicitly done
Notes	In-hospital Ottawa, London (Canada) 1993 to 1995

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Selective reporting (reporting bias)	Low risk	
Blinding of participants and personnel (performance bias) All outcomes	High risk	
Blinding of outcome assessment (detection bias) Mortality	Low risk	
Blinding of outcome assessment (detection bias) Neurological status	Low risk	

Stiell-Prehospital 1996

Methods	Randomised controlled trial
Participants	n = 1011 Mean age: 68 years

Stiell-Prehospital 1996 (Continued)

Male: 63%

Exclusions: trauma, excessive delay

VF: 32.5%

Cardiac antecedents: 49%

Cardiac cause of heart arrest: 86%

Respiratory cause: 8%

Interventions	ACDR vs STR Only paramedics in responder team Mean response time: 5.2 minutes Adrenaline dose: ?
Outcomes	<ul style="list-style-type: none"> • Immediate and at-hospital discharge mortality • Neurological outcome • Complications Intention-to-treat analysis was explicitly done
Notes	Prehospital Ottawa, London (Canada) 1993 to 1995

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	Low risk	
Allocation concealment (selection bias)	Low risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Selective reporting (reporting bias)	Low risk	
Blinding of participants and personnel (performance bias) All outcomes	High risk	
Blinding of outcome assessment (detection bias) Mortality	Low risk	
Blinding of outcome assessment (detection bias) Neurological status	Low risk	

Tucker 1994

Methods	Randomised controlled trial
Participants	n = 53 Mean age: 71 years Male: 43% Exclusions: trauma victims, pregnancy VF: 28% Cardiac antecedents: 58%
Interventions	ACDR vs STR Physician in responder team Mean response time: 2 minutes Adrenaline dose: ?
Outcomes	<ul style="list-style-type: none"> • Immediate and at-hospital discharge mortality • Neurological outcome Intention-to-treat analysis was explicitly done
Notes	In-hospital San Francisco (USA) 1992 to 1993

Risk of bias

Bias	Authors' judgement	Support for judgement
Random sequence generation (selection bias)	High risk	
Allocation concealment (selection bias)	High risk	
Incomplete outcome data (attrition bias) All outcomes	Low risk	
Selective reporting (reporting bias)	Low risk	All outcomes analysed in the review had been reported adequately
Blinding of participants and personnel (performance bias) All outcomes	High risk	
Blinding of outcome assessment (detection bias) Mortality	Low risk	
Blinding of outcome assessment (detection bias)	Unclear risk	Not stated

Tucker 1994 *(Continued)*
Neurological status

n = number of participants included in the study.

VF = presenting ventricular fibrillation or ventricular tachycardia as initial electrical rhythm.

ACDR = active chest compression-decompression resuscitation.

STR = standard resuscitation (manual chest compression).

Characteristics of excluded studies *[ordered by study ID]*

Study	Reason for exclusion
Arai 2001	Not randomised
Aufderheide 2011	Therapeutic interventions other than the method of chest compression were different: ACDR was combined with an inspiratory impedance threshold device (ITD). Control group received neither ACDR nor ITD
Cohen 1993	60% of included participants had a known pre-existing terminal disease
Gueugniaud 1998	Participants were randomised to receive high or standard doses of adrenaline. Some participants included in this study received ACDR, but they were not randomised to receive ACDR or STR
Lefrançois 1998	Not randomised
Panzer 1996	Retrospective, not randomised
Plaisance 2004	ACDR CPR was applied to all participant groups. This trial studied the effect of a respiratory impedance threshold device compared to usual ventilation
Rivers 1993	Alternation of different methods of chest compression on the same participant
Wolcke 2003	Therapeutic interventions other than the method of chest compression were different: ACDR was combined with an inspiratory impedance threshold device (ITD). Control group received neither ACDR nor ITD

Characteristics of studies awaiting assessment *[ordered by study ID]*
He 2003

Methods	Participants were allocated to ACD-CPR or standard CPR randomly (no details known)
Participants	92 participants with cardiac arrest occurring out-of-hospital in Sichuan, China
Interventions	ACDR CPR (cardio pump) or standard CPR
Outcomes	<ul style="list-style-type: none"> Return of spontaneous circulation and admission to hospital
Notes	Only data from abstract known. No figures given. It is said that "On arriving to the hospital, the survival rate was higher in the ACD-CPR group, but of no statistical significance." The full text of this publication is awaiting translation from Chinese

DATA AND ANALYSES

Comparison 1. Out-of-hospital cardiac arrests

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Immediate mortality	10	4162	Risk Ratio (M-H, Random, 95% CI)	0.98 [0.94, 1.03]
2 Mortality at hospital discharge	9	3412	Risk Ratio (M-H, Fixed, 95% CI)	0.99 [0.98, 1.01]
3 Neurological impairment in survivors	5	358	Risk Ratio (M-H, Fixed, 95% CI)	1.74 [1.06, 2.83]
3.1 Moderate neurological impairment	4	107	Risk Ratio (M-H, Fixed, 95% CI)	0.98 [0.34, 2.79]
3.2 Severe neurological impairment	4	107	Risk Ratio (M-H, Fixed, 95% CI)	3.11 [0.98, 9.83]
3.3 Any neurological impairment (any severity)	5	144	Risk Ratio (M-H, Fixed, 95% CI)	1.71 [0.90, 3.25]
4 Complications	7	3032	Risk Ratio (M-H, Fixed, 95% CI)	1.09 [0.86, 1.38]

Analysis 1.1. Comparison 1 Out-of-hospital cardiac arrests, Outcome 1 Immediate mortality.

Analysis 1.2. Comparison 1 Out-of-hospital cardiac arrests, Outcome 2 Mortality at hospital discharge.

Analysis 1.3. Comparison 1 Out-of-hospital cardiac arrests, Outcome 3 Neurological impairment in survivors.

Analysis 1.4. Comparison 1 Out-of-hospital cardiac arrests, Outcome 4 Complications.

Comparison 2. In-hospital cardiac arrests

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Immediate mortality	2	826	Risk Ratio (M-H, Fixed, 95% CI)	0.98 [0.88, 1.08]
2 Mortality at hospital discharge	2	826	Risk Ratio (M-H, Fixed, 95% CI)	1.00 [0.95, 1.05]
3 Neurological impairment in survivors	2	279	Risk Ratio (M-H, Fixed, 95% CI)	1.19 [0.63, 2.25]
3.1 Moderate neurologic impairment	2	93	Risk Ratio (M-H, Fixed, 95% CI)	0.5 [0.10, 2.58]
3.2 Severe neurologic impairment	2	93	Risk Ratio (M-H, Fixed, 95% CI)	1.95 [0.59, 6.50]
3.3 Any neurological impairment (any severity)	2	93	Risk Ratio (M-H, Fixed, 95% CI)	1.19 [0.50, 2.86]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
4 Complications	1	773	Risk Ratio (M-H, Fixed, 95% CI)	0.97 [0.49, 1.93]

Analysis 2.1. Comparison 2 In-hospital cardiac arrests, Outcome 1 Immediate mortality.

Analysis 2.2. Comparison 2 In-hospital cardiac arrests, Outcome 2 Mortality at hospital discharge.

Analysis 2.3. Comparison 2 In-hospital cardiac arrests, Outcome 3 Neurological impairment in survivors.

Analysis 2.4. Comparison 2 In-hospital cardiac arrests, Outcome 4 Complications.

Comparison 3. Subgroup analysis: physician in first responding team or only paramedics

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Immediate mortality	10	4162	Risk Ratio (M-H, Fixed, 95% CI)	0.98 [0.94, 1.01]
1.1 Physician in first responding team	5	1487	Risk Ratio (M-H, Fixed, 95% CI)	0.96 [0.89, 1.04]
1.2 Only paramedics in first responding team	5	2675	Risk Ratio (M-H, Fixed, 95% CI)	0.98 [0.95, 1.02]
2 Mortality at hospital discharge	9	3412	Risk Ratio (M-H, Fixed, 95% CI)	0.99 [0.98, 1.01]

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
2.1 Physician in first responding team	4	737	Risk Ratio (M-H, Fixed, 95% CI)	0.99 [0.94, 1.04]
2.2 Only paramedics in first responding team	5	2675	Risk Ratio (M-H, Fixed, 95% CI)	1.00 [0.98, 1.01]
3 Neurological impairment in survivors (any severity)	5	144	Risk Ratio (M-H, Fixed, 95% CI)	1.71 [0.90, 3.25]
3.1 Physician in first responding team	2	44	Risk Ratio (M-H, Fixed, 95% CI)	1.07 [0.41, 2.80]
3.2 Only paramedics in first responding team	3	100	Risk Ratio (M-H, Fixed, 95% CI)	2.19 [0.93, 5.13]

Analysis 3.1. Comparison 3 Subgroup analysis: physician in first responding team or only paramedics, Outcome 1 Immediate mortality.

Analysis 3.2. Comparison 3 Subgroup analysis: physician in first responding team or only paramedics, Outcome 2 Mortality at hospital discharge.

Analysis 3.3. Comparison 3 Subgroup analysis: physician in first responding team or only paramedics, Outcome 3 Neurological impairment in survivors (any severity).

Comparison 4. Sensitivity analysis: best-quality studies

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Immediate mortality	12	4988	Risk Ratio (M-H, Fixed, 95% CI)	0.98 [0.95, 1.01]
1.1 Allocation concealment adequate	5	2460	Risk Ratio (M-H, Fixed, 95% CI)	1.01 [0.96, 1.06]
1.2 Allocation concealment unclear	1	61	Risk Ratio (M-H, Fixed, 95% CI)	1.13 [0.77, 1.65]
1.3 Allocation concealment inadequate	6	2467	Risk Ratio (M-H, Fixed, 95% CI)	0.94 [0.90, 0.99]
2 Mortality at hospital discharge	11	4238	Risk Ratio (M-H, Fixed, 95% CI)	1.00 [0.98, 1.01]
2.1 Allocation concealment adequate	5	2460	Risk Ratio (M-H, Fixed, 95% CI)	1.00 [0.97, 1.02]
2.2 Allocation concealment unclear	1	61	Risk Ratio (M-H, Fixed, 95% CI)	1.04 [0.87, 1.25]
2.3 Allocation concealment inadequate	5	1717	Risk Ratio (M-H, Fixed, 95% CI)	0.99 [0.97, 1.02]
3 Neurological impairment in survivors (any severity)	7	237	Risk Ratio (M-H, Fixed, 95% CI)	1.50 [0.89, 2.51]
3.1 Allocation concealment adequate	3	163	Risk Ratio (M-H, Fixed, 95% CI)	1.45 [0.75, 2.79]
3.2 Allocation concealment unclear	1	7	Risk Ratio (M-H, Fixed, 95% CI)	0.89 [0.33, 2.37]
3.3 Allocation concealment inadequate	3	67	Risk Ratio (M-H, Fixed, 95% CI)	2.09 [0.67, 6.54]

Analysis 4.1. Comparison 4 Sensitivity analysis: best-quality studies, Outcome 1 Immediate mortality.

Analysis 4.2. Comparison 4 Sensitivity analysis: best-quality studies, Outcome 2 Mortality at hospital discharge.

Analysis 4.3. Comparison 4 Sensitivity analysis: best-quality studies, Outcome 3 Neurological impairment in survivors (any severity).

Comparison 5. Sensitivity analysis: largest (n > 500) studies

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Immediate mortality	5	3815	Risk Ratio (M-H, Fixed, 95% CI)	0.97 [0.93, 1.00]
2 Mortality at hospital discharge	4	3065	Risk Ratio (M-H, Fixed, 95% CI)	1.00 [0.98, 1.02]
3 Neurological impairment in survivors (any severity)	3	159	Risk Ratio (M-H, Fixed, 95% CI)	1.60 [0.81, 3.16]

Analysis 5.1. Comparison 5 Sensitivity analysis: largest (n > 500) studies, Outcome 1 Immediate mortality.

Analysis 5.2. Comparison 5 Sensitivity analysis: largest (n > 500) studies, Outcome 2 Mortality at hospital discharge.

Analysis 5.3. Comparison 5 Sensitivity analysis: largest (n > 500) studies, Outcome 3 Neurological impairment in survivors (any severity).

APPENDICES

Appendix 1. Search strategies 2008

CENTRAL Issue 2, 2008

- #1 MeSH descriptor heart arrest explode all trees
- #2 heart next arrest* in All Text
- #3 cardiac next arrest* in All Text
- #4 sudden next death in All Text
- #5 MeSH descriptor Cardiopulmonary Resuscitation this term only
- #6 resuscitation in All Text
- #7 (#1 or #2 or #3 or #4 or #5 or #6)
- #8 active next compression in All Text
- #9 acdr in All Text
- #10 acd-cpr in All Text
- #11 acd in All Text
- #12 decompression in All Text
- #13 CardioPump in All Text
- #14 (#8 or #9 or #10 or #11 or #12 or #13)
- #15 (#7 and #14)

MEDLINE (Ovid) 1966 to May 2008

1 exp Heart Arrest/
2 heart arrest\$.tw.
3 cardiac arrest\$.tw.
4 sudden death.tw.
5 Cardiopulmonary Resuscitation/
6 resuscitation.tw.
7 or/1-6
8 active compression.tw.
9 acdr.tw.
10 acd-cpr.tw.
11 acd.tw.
12 decompression.tw.
13 cardiopump.tw.
14 or/8-13
15 7 and 14
16 randomized controlled trial.pt.
17 controlled clinical trial.pt.
18 Randomized controlled trials/
19 random allocation/
20 double blind method/
21 single-blind method/
22 or/16-21
23 exp animal/ not humans/
24 22 not 23
25 clinical trial.pt.
26 exp Clinical trials/
27 (clin\$ adj25 trial\$).ti,ab.
28 ((singl\$ or doubl\$ or trebl\$ or tripl\$) adj (blind\$ or mask\$)).ti,ab.
29 placebos/
30 placebo\$.ti,ab.
31 random\$.ti,ab.
32 research design/
33 or/25-32
34 33 not 23
35 34 or 24
36 35 and 15

EMBASE (Ovid) 1980 to May 2008

1 resuscitation/
2 exp Heart Arrest/
3 heart arrest\$.tw.
4 cardiac arrest\$.tw.
5 sudden death.tw.
6 resuscitation/
7 resuscitation.tw.
8 or/2-7
9 active compression.tw.
10 acdr.tw.
11 acd-cpr.tw.
12 acd.tw.
13 decompression.tw.
14 cardiopump.tw.
15 or/9-14
16 8 and 15
17 clinical trial/
18 random\$.tw.
19 randomized controlled trial/
20 trial\$.tw.
21 follow-up.tw.
22 double blind procedure/

23 placebo\$.tw.
24 placebo/
25 factorial\$.ti,ab.
26 (crossover\$ or cross-over\$).ti,ab.
27 (double\$ adj blind\$).ti,ab.
28 (singl\$ adj blind\$).ti,ab.
29 assign\$.ti,ab.
30 allocat\$.ti,ab.
31 volunteer\$.ti,ab.
32 Crossover Procedure/
33 Single Blind Procedure/
34 or/17-33
35 exp animal/
36 nonhuman/
37 exp animal experiment/
38 or/35-37
39 exp human/
40 38 not 39
41 34 not 40

Appendix 2. Search strategies 2010 and 2013

CENTRAL

#1 MeSH descriptor Heart Arrest explode all trees
#2 heart next arrest*
#3 cardiac next arrest*
#4 sudden next death
#5 MeSH descriptor Cardiopulmonary Resuscitation, this term only
#6 resuscitation
#7 (#1 OR #2 OR #3 OR #4 OR #5 OR #6)
#8 active next compression
#9 acdr
#10 acd-cpr
#11 acd
#12 decompression
#13 CardioPump
#14 (#8 OR #9 OR #10 OR #11 OR #12 OR #13)
#15 (#7 AND #14)

MEDLINE (OVID)

1. exp Heart Arrest/
2. heart arrest\$.tw.
3. cardiac arrest\$.tw.
4. sudden death.tw.
5. Cardiopulmonary Resuscitation/
6. resuscitation.tw.
7. or/1-6
8. active compression.tw.
9. acdr.tw.
10. acd-cpr.tw.
11. acd.tw.
12. decompression.tw.
13. cardiopump.tw.
14. or/8-13
15. 7 and 14
16. randomized controlled trial.pt.
17. controlled clinical trial.pt.
18. randomized.ab.
19. placebo.ab.
20. drug therapy.fs.
21. randomly.ab.

22. trial.ab.
23. groups.ab.
24. 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23
25. exp animals/ not humans.sh.
26. 24 not 25
27. ((2008\$ not (200801\$ or 200802\$ or 200803\$ or 200804\$)) or 2009\$ or 2010\$).ed.
28. 15 and 26 and 27

EMBASE (OVID)

1. resuscitation/
2. heart arrest/
3. heart arrest\$.tw.
4. sudden death.tw.
5. resuscitation.tw.
6. cardiac arrest\$.tw.
7. or/1-6
8. active compression.tw.
9. acdr.tw.
10. acd-cpr.tw.
11. acd.tw.
12. decompression.tw.
13. cardiopump.tw.
14. or/8-13
15. 7 and 14
16. random\$.tw.
17. factorial\$.tw.
18. crossover\$.tw.
19. cross over\$.tw.
20. cross-over\$.tw.
21. placebo\$.tw.
22. (doubl\$ adj blind\$).tw.
23. (singl\$ adj blind\$).tw.
24. assign\$.tw.
25. allocat\$.tw.
26. volunteer\$.tw.
27. crossover procedure/
28. double blind procedure/
29. randomized controlled trial/
30. single blind procedure/
31. 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30
32. (animal/ or nonhuman/) not human/
33. 31 not 32
34. 15 and 33
35. ((2008\$ not ("200801" or "200802" or "200803" or "200804" or "200805" or "200806" or "200807" or "200808" or "200809" or "200810" or "200811" or "200812" or "200813" or "200814" or "200815" or "200816" or "200817")) or 2009\$ or 2010\$).em.
36. 34 and 35

WHAT'S NEW

Date	Event	Description
10 November 2014	Review declared as stable	Since 2004 there have been no new studies found for inclusion. On this basis the decision has been taken to stop updating this review.

HISTORY

Protocol first published: Issue 4, 2000

Active chest compression-decompression for cardiopulmonary resuscitation (Review)

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Review first published: Issue 3, 2001

Date	Event	Description
4 September 2013	New citation required but conclusions have not changed	No new trials were located.
16 April 2013	New search has been performed	Searches were re-run: 27 new publications were found, but none fulfilled the inclusion criteria. No new trial was included, and conclusions did not change.
29 June 2010	New search has been performed	Searches were re-run for this update in June 2010. 8 new publications were found, but none included. The conclusion remains unchanged
13 May 2009	Amended	No changes - republished to fix technical problem
21 May 2008	New search has been performed	In the current update, we reran the search to May 2008. 4 new publications found and assessed, but none included. Conclusions unchanged
16 May 2008	Amended	Converted to new review format.
30 January 2004	New search has been performed	In this update, we reran the search for primary studies up to January 2004. 2 new studies were found, assessed and excluded from the review. The studies were excluded because 1 study was not randomised, and the other treated the intervention, active chest compression-decompression (ACDR CPR) and the control groups differently. The conclusions were unchanged
31 May 2002	New search has been performed	In this update, we reran the search for randomised controlled trials up to May 2002. No new trials were found. The conclusions were unchanged

CONTRIBUTIONS OF AUTHORS

Carmelo Lafuente-Lafuente: conception and design of the review, draft of the protocol, search for primary studies, assessing papers for inclusion and quality, extracting data, analysis and interpretation of data, writing the review.

María Melero-Bascones: draft of the protocol, screening search results, retrieval of papers, assessing papers for inclusion and quality, extracting data from papers, writing the review.

DECLARATIONS OF INTEREST

None known.

SOURCES OF SUPPORT

Internal sources

- Complejo Hospitalario Universitario de Albacete, Spain.
- Hôpital Charles Foix, groupe hospitalier Pitié-Salpêtrière-Charles Foix, Paris, France.

Allocating time to the main author to allow them to do this work

External sources

- No sources of support supplied

DIFFERENCES BETWEEN PROTOCOL AND REVIEW

There were none; we applied the protocol as initially defined.

INDEX TERMS

Medical Subject Headings (MeSH)

Cardiopulmonary Resuscitation [instrumentation] [*methods]; Emergency Medical Services; Heart Arrest [*therapy]; Heart Massage [instrumentation] [methods]; Out-of-Hospital Cardiac Arrest [therapy]; Randomized Controlled Trials as Topic; Treatment Outcome

MeSH check words

Adult; Humans