Original Ariticle

Active compression-decompression cardiopulmonary resuscitation (CPR) versus standard CPR for cardiac arrest patients: a meta-analysis

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BACKGROUND: Active compression-decompression cardiopulmonary resuscitation (ACD-CPR) has been popular in the treatment of patients with cardiac arrest (CA). However, the effect of ACD-CPR versus conventional standard CPR (S-CRP) is contriversial. This study was to analyze the efficacy and safety of ACD-CPR versus S-CRP in treating CA patients.

METHODS: Randomized or quasi-randomized controlled trials published from January 1990 to March 2011 were searched with the phrase "active compression-decompression cardiopulmonary resuscitation and cardiac arrest" in PubMed, EmBASE, and China Biomedical Document Databases. The Cochrane Library was searched for papers of meta-analysis. Restoration of spontaneous circulation (ROSC) rate, survival rate to hospital admission, survival rate at 24 hours, and survival rate to hospital discharge were considered primary outcomes, and complications after CPR were viewed as secondary outcomes. Included studies were critically appraised and estimates of effects were calculated according to the model of fixed or random effects. Inconsistency across the studies was evaluated using the I^2 statistic method. Sensitivity analysis was made to determine statistical heterogeneity.

RESULTS: Thirteen studies met the criteria for this meta-analysis. The studies included 396 adult CA patients treated by ACD-CPR and 391 patients by S-CRP. Totally 234 CA patients were found out hospitals, while the other 333 CA patients were in hospitals. Two studies were evaluated with high-quality methodology and the rest 11 studies were of poor quality. ROSC rate, survival rate at 24 hours and survival rate to hospital discharge with favorable neurological function indicated that ACD-CPR is superior to S-CRP, with relative risk (RR) values of 1.39 (95% *CI* 0.99–1.97), 1.94 (95% *CI* 1.45–2.59) and 2.80 (95% *CI* 1.60–5.24). No significant differences were found in survival rate to hospital admission and survival rate to hospital discharge for ACD-CPR versus S-CRP with RR values of 1.06 (95% *CI* 0.76–1.60) and 1.00 (95% *CI* 0.73–1.38).

CONCLUSION: Quality controlled studies confirmed the superiority of ACD-CPR to S-CRP in terms of ROSC rate and survival rate at 24 hours. Compared with S-CRP, ACD-CPR could not improve survival rate to hospital admission or survival rate to hospital discharge.

KEY WORDS: Active compression-decompression; Cardiopulmonary resuscitation; Cardiac arrest; Meta-analysis

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INTRODUCTION

Cardiac arrest (CA) seizes a large number of lives all around the world and causes increasing global concern. Approximately 400 000 to 460 000 people in the USA may die every year from sudden CA in the emergency department or before arrival at a hospital.[1] Standard CPR (S-CRP) has been used for cardiopulmonary resuscitation.[2] However, the mortality has not improved remarkably after S-CRP. The reported success rate of CPR ranged from 5% to 10%.[3] The reported coronary

perfusion pressure (CPP), which was closely related to the successful resuscitation, was far from normal in patients with CA receiving S-CRP.[4] Active compression-decompression cardiopulmonary resuscitation (ACD-CPR) with a hand-held suction device is applied on the mid sternum to compress the chest and then to actively decompress the chest after each compression. European Resuscitation Council Guidelines for Resuscitation 2010 does not recommend ACD-CPR as an option for CRP in CA patients.[5] However, recent studies demonstrated that ACD-CPR improved clinical outcome compared with S-CRP[5] and that the curative effect of ACD-CRP and S-CRP was not consistent in CA patients. Based on a systematic review and meta-analysis of the literature, we assessed existing evidences about the efficacy and safety of ACD-CRP and S-CRP in the management of CA.

METHODS

Search strategy

Studies were searched in PubMed, EmBASE, and China Biomedical Document Database from January 1990 to May 2011 by using the following terms: Active compression-decompression cardiopulmonary resuscitation, cardiac arrest, and cardiopulmonary resuscitation. The Cochrane database of systematic reviews was searched using such phrase as active compression-decompression cardiopulmonary resuscitation.

Inclusion and exclusion criteria

Inclusion criteria were as follows: 1) randomized or quasi-randomized controlled studies in adults (more than 18 years) diagnosed with CA at in-patient or out-patient clinics; 2) intervention with ACD-CRP; 3) intervention with S-CRP as control; 4) English and Chinese languages; 5) results including at least one of the following variables: ROSC rate, survival rate at 24 hours, survival rate to hospital admission, survival rate to hospital discharge, survival rate to hospital discharge without neurological impairment and complications of CPR. Exclusion criteria were as follows: 1) animal studies; 2) patients studied under 18 years old; 3) non-randomized studies; 4) studies far from our purpose of the study.

Selection of studies

The included studies were examined by two independent reviewers, and disagreements were handled by discussion.

Data extraction

Original data were extracted on a standard form, which includes: 1) the general information of selected studies, including details of study design, and randomized-blind criteria; 2) study population; 3) intervention and comparison and 4) measures of efficacy and safety.

Analysis of methodological quality and scientific evidence

The methodology in all the studies was analyzed including: 1) random distribution; 2) allocation concealment; 3) blind method if any; 4) studies lost or not; 5) quality evaluation of intention treatment. Jadad score was applied to evaluate the studies, the method was considered of low quality when the score was 1–2 and of high quality when it was 3–5.[6]

Data analysis and synthesis of results

Standard meta-analytical techniques were used to determine the efficacy and safety of ACD-CRP and S-CRP, using a model of fixed or random effects.[7] We analyzed dichotomous variables by estimation of relative risk (RR) with a 95% confidence interval as well as continuous variables by weighted mean difference (WMD) with a 95% confidence interval. The degree of inconsistency between the studies was quantified using the I^2 statistical method that describes the proportion of variance across the studies because I^2<50% and I^2>50% reflect small and large inconsistency respectively.[8] The sensitivity of the method was analyzed to explore statistical heterogeneity.[9] As in recent studies, we did not use funnel plots to examine the possibility of publication bias.[10]

RESULTS

Searching results

In 151 articles searched, 130 were reviews and editorials, investigations, analytical studies, and case reports. Sixty animal studies were excluded and another 4 studies were excluded because their intervention groups did not use ACD-CRP. Furthermore, two studies were published in duplication. The latest study was selected. Finally, 13 randomly controlled trials were included into this meta-analysis involving 2 353 CA patients.[11–23] Thus 1 252 patients accepted ACD-CRP, and 1 252 received S-CRP (Figure 1).

Included studies

Among the included studies, 4 were accomplished in Germany, 2 in France, 2 in Canada, and 1 in Australia. The rest 4 studies were conducted in the USA (2 studies)

and China (2 studies). The four studies included patients with CA encountered in hospitals while the other studies included patients with CA out hospitals. Only Stiell studied both out-hospital and in-hospital CA patients. The four studies were multi-center control studies, and the other studies were single-center control studies. Stiell et al[21] studied a largest sample of 2 000 patients, while Tucker et al[23] studied 53 patients, comparatively the smallest sample. Six studies provided ROSC rate, 4 with survival rate at 24 hours, 2 with survival rate to hospital admission, 4 with survival rate to hospital discharge, and 5 with complications of CPR (Table 1).

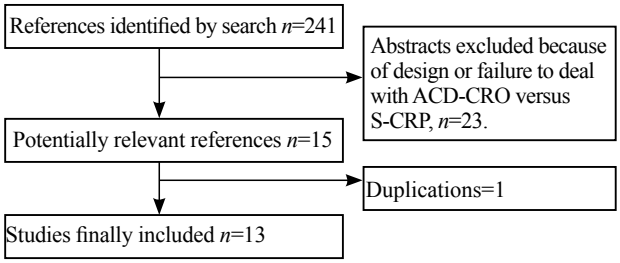

Figure 1. Searching strategy.

Methodology of the included studies

In 13 studies included in this analysis, there was no significant difference in baseline conditions. Four studies described the details of randomization. Only one study provided double blind allocation, while the rest did not mention it. In four studies using concealed allocation, only two were appropriate. According to Jadad scoring, more than three scores were found in two studies which were considered of high-quality methodology, while the rest studies were not satisfied with scores fewer than 3 (Table 2).

ROSC rate

Six studies provided specific data on ROSC rate. The

Table 1. General information about included studies

Author	Patients (T/C)	Age	Treatment (T/C)	Outcome	Circumstances where patients confronted CA	Country
2009 Chen SP	109/109	≥18	T: ACD-CPR C: standard CRP	ROSC Survival rate at 24 hours	Out-of-hospital	China
2003 He Q	46/46	≥18	T: ACD-CPR C: standard CRP	ROSC Survival rate to hospital admission	In-hospital	China
1999 Baubin M	33/15	≥18	T1: ACD-CPR C: standard CRP	Ventricular fibrillation Complications of CPR (sternal fractures)	Out-of-hospital	Australia
1999 Plaisance P	373/377	≥18	T: ACD-CPR C: standard CRP	Hospital discharge rate without neurologic impairment One-year survival rate	Out-of-hospital	France
1997 Mauer D	-	≥18	T: ACD-CPR C: standard CRP	Survival rate Neurological outcome Complications of CPR	Out-of-hospital	Germany
1997 Plaisance P	254/258	≥18	T: ACD-CPR C: standard CRP	ROSC Survival rate at 1 hour, 24 hours, and 1 month Survival rate to hospital discharge without neurological impairment Neurological outcome Complications of CPR	Out-of-hospital	France
1996 Luiz T	26/30	≥18	T: ACD-CPR C: standard CRP	ROSC Mean carbon dioxide content	Out-of-hospital	Germany
1996 Mauer D	106/114	≥18	T: ACD-CPR C: standard CRP	ROSC Survival rate to hospital admission Survival rate to hospital discharge Neurological outcome (CPC and OPC) Complications of CPR	Out-of-hospital	Germany
1996 Stiell IG	405/368	≥18	T: ACD-CPR C: standard CRP	Survival rate to hospital discharge Neurological outcome	In-hospital	Canada
1996 Stiell IG	501/510	≥18	T: ACD-CPR C: standard CRP	Survival rate to hospital discharge Neurological outcome	Out-of-hospital	Canada
1994 Ellinger K	26/30	≥18	T: ACD-CPR C: standard CRP	ROSC Survival rate to hospital discharge Complications of CPR	Out-of-hospital	Germany
1994 Tucker KJ	25/28	≥18	T: ACD-CPR C: standard CRP	ROSC Survival rate at 24 hours Surivival rate to hospital discharge	In-hospital	USA
1993 Cohen TJ	29/33	≥18	T: ACD-CPR C: standard CRP	Rages of initial resuscitation Survival rate at 24 hours Survival rate to hospital discharge Neurological outcome	In-hospital	USA

ACD-CRP group included 566 patients, and the S-CRP group consisted of 585 patients. There was significant difference among the studies (P=0.002, I^2=74.4%). The calculated RR merger was 1.39 (95% *CI* 0.99–1.97), and analysis showed a significant improvement of ROSC rate in the ACD-CRP group compared with the S-CRP group (Figure 2).

Survival rate to hospital admission

Two studies provided specific data on survival rate to hospital admission for out hospital patients. The ACD-CRP group included 162 patients and the S-CRP group comprised 160 patients. No statistical heterogeneity was seen in the studies (P=0.45, I^2=0%), so the model of fixed effects was used for analysis. The calculated OR merger was 1.06 (95% *CI* 0.76–1.60), and joint analysis also showed no significant difference in survival rate to hospital admission in the ACD-CRP group compared with the S-CRP group (Figure 3).

Survival rate at 24 hours

Four studies provided specific data on survival rate

Table 2. Quality of the included studies

Author	Random method	Blind allocation	Concealed allocation	Exit/Out of research	Comparability of base line	Jadad score
2009 Chen SP	Not described	No	No	No	Yes	1
2003 He Q	Not described	No	No	No	Yes	1
1999 Baubin M	Not described	No	No	No	Yes	1
1999 Plaisance P	Assigned on an even or odd day of the month	No	Yes	No	Yes	2
1999 Sklgvoll E	A random number tag	No	Yes	No	Yes	3
1997 Mauer D	Not described	No	No	No	Yes	1
1997 Plaisance P	Assigned on an even or odd day of the month	No	No	No	Yes	1
1996 Luiz T	Not described	No	No	No	Yes	1
1996 Mauer D	Not described	No	No	No	Yes	1
1996 Stiell IG	Allocation by using a sealed container	Yes	Yes	No	Yes	5
1994 Ellinger K	Not described	No	No	No	Yes	1
1994 Tucker KJ	Not described	No	No	No	Yes	1
1993 Cohen TJ	Assigned on medical-record numbers	No	Yes	No	Yes	2
1993 Pell AC	Not described	No	No	No	Yes	1

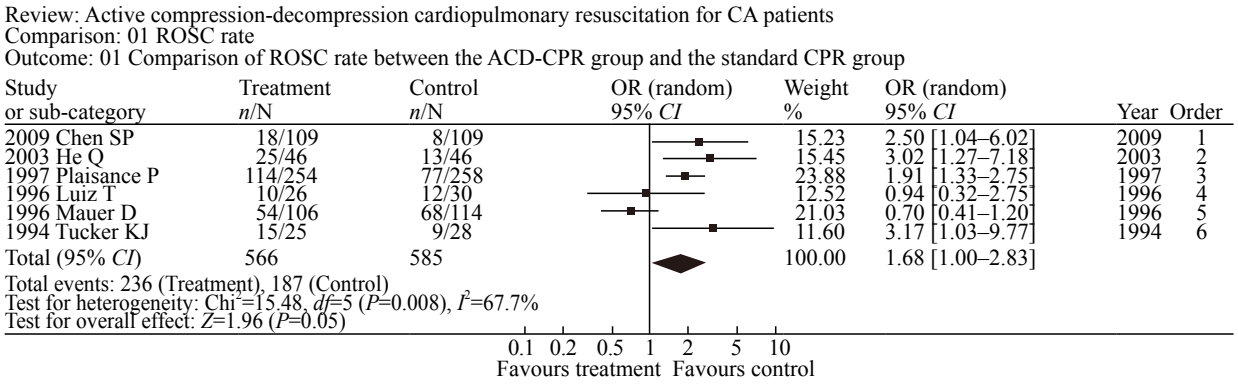

Figure 2. Comparison of ROSC rate between the ACD-CPR group and the S-CPR group.

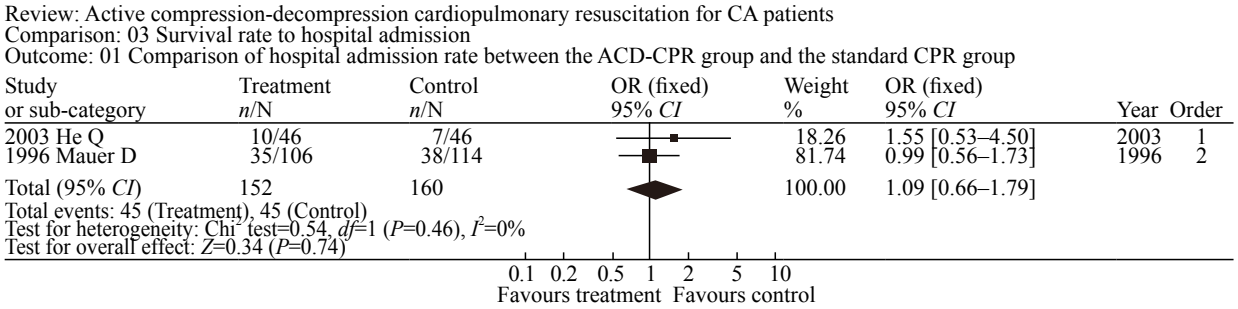

Figure 3. Comparison of hospital admission rate between the ACD-CPR group and the S-CPR group.

at 24 hours. The ACD-CRP group included 417 patients, and the S-CRP group 428 patients. No significant heterogeneity was seen in the studies (P=0.78, I^2=0%), thus random effects were analyzed. The calculated OR merger was 1.94 (95% *CI* 1.45–2.59), and joint analysis also showed a significant improvement in survival rate at 24 hours in the ACD-CRP group compared with the S-CRP group (Figure 4).

Survival rate to hospital discharge

Four studies provided specific data on survival rate to hospital discharge. The ACD-CRP group included 608 patients and the S-CRP group 583 patients. No statistically heterogeneity was found in the studies (P=0.39, I^2=0.9%), thus fixed effects were analyzed. The calculated RR merger was 1.00 (95% *CI* 0.73–1.38), and joint analysis also showed no significant difference in survival rate to hospital discharge in the ACD-CRP group compared with the S-CRP group (Figure 5).

Complications of CPR

Five studies described complications after CPR; however, data were difficult to collect for analysis. Instead, descriptive studies were used for evaluating complications after CPR. It was reported that there were more sternal fractures and rib fractures (13/15 vs. 11/20; P<0.05) in ACD-CPR patients than in STD-CPR patients (14/15 vs. 6/20; P<0.005). Also sternal dislodgements (2.9% vs. 0.4%, P=0.03) and hemoptysis (5.4% vs. 1.3%, P=0.01) were more frequent in ACD ACLS patients. Others found that there was no difference in the incidence of complications caused by CPR.

DISCUSSION

The American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care 2010 recommend premier selection of standard CPR for CA patients in and out of hospital.[2] However, studies showed that standard CPR can only supply vital organs with limited blood pressure (BP),[24] even specialists are unable to perform high-quality resuscitation because of energy consumption.[25] The overall survival rate after cardiac arrest remains low. In 74 studies involving 36 communities as reported, the survival rate ranged from 2% to 44%.[26] The increase of CPP was found to be closely related to successful resuscitation.[2] Chest expansion after segues can suck blood into the heart where blood is ready for the next pump. The more the chest is expanded, the more

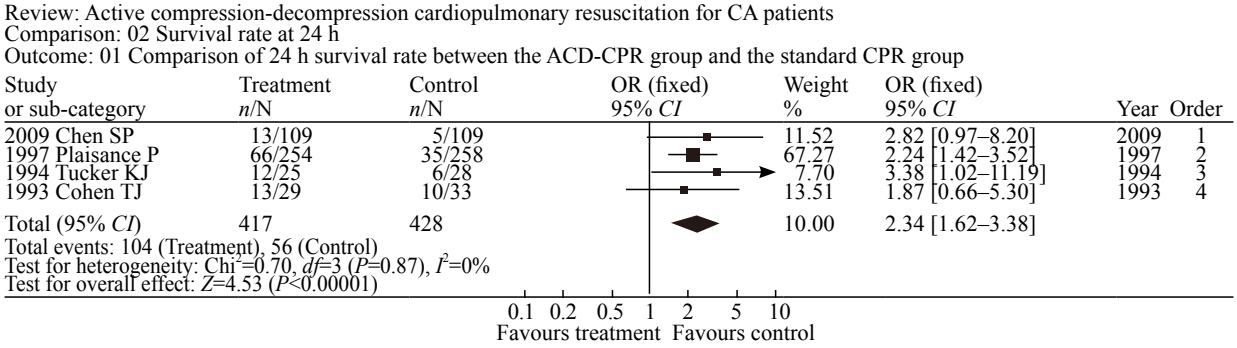

Figure 4. Survival rate comparison at 24 hours between the ACD-CPR group and the S-CPR group.

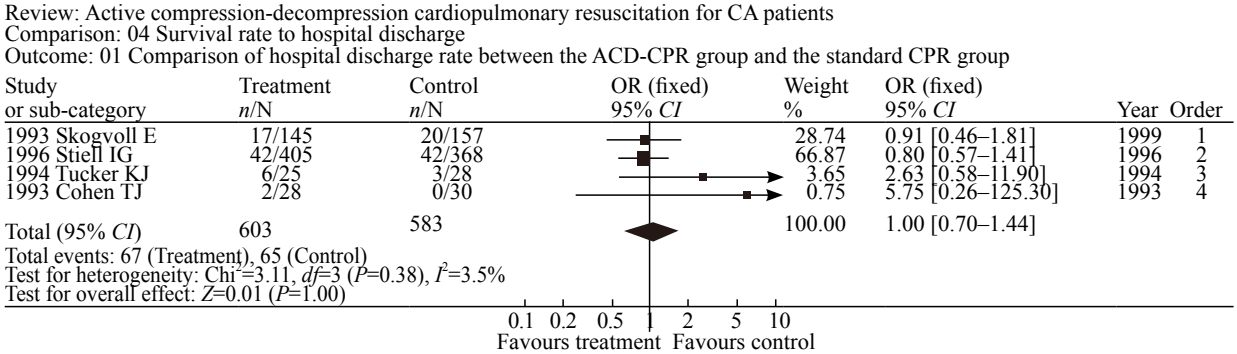

Figure 5. Hospital discharge rate comparison between the ACD-CPR group and the S-CPR group.

cardiac output is given. During ACD-CPR, positive and negative pressures are used alternately to the chest by a "plunger" that forms a seal with the anterior chest wall. Several studies found that ACD-CPR produced better hemodynamic effects than standard CPR in patients,[27–29] but there were exceptions.[30]

The results of this meta-analysis indicate that ACD-CPR is superior to STD-CPR for CA patients in terms of ROSC rate, survival rate at 24 hours, and admission rate. However, survival rate to hospital discharge is not statistically significant. ACD-CPR can be used to impove the neurological outcome at discharge or to produce a better long-term outcome. This finding is not consistent with the published meta-analyses, suggesting that ACD-CPR is not beneficial to patients with CA.[31] This meta-analysis showed an increased rate of complications including sternal fracture which might be associated with ACD-CPR. Sternal fracture is unlikely to increase mortality because it causes no severe internal organ damage.

In this meta-analysis, methodological quality was not high in most of quasi-randomized controlled trials because only Chinese and English articles were reviewed. Large-scale multi-center randomized, controlled clinical studies on ACD-CRP for CA patients are needed.

The price of ACD-CPR device is acceptable for any hospital. However, the efficacy of ACD-CPR may be highly dependent on the quality and duration of training.[32]

In conclusion, compared with S-CPR, ACD–CPR can improve the ROSC rate and survival rate at 24 hours. There is no difference in hospital admission rate and hospital discharge rate between S-CPR and ACD-CPR patients. More studies are needed to provide sufficient evidence for clinical practice.

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Ethical approval: Not needed.

Conflicts of interest: The authors declare that there is no conflict of interest.

Contributors: Luo XR proposed the study, analyzed the data and wrote the first draft. All authors contributed to the design and interpretation of the study and to further drafts.

REFERENCES

1 Zheng ZJ, Croft JB, Giles WH, Mensah GA. Sudden cardiac death in the United States, 1989 to 1998. Circulation 2001; 104: 2158–2163.
2 Neumar RW, Otto CW, Link MS, Kronick SL, Shuster M, Callaway CW, et al. Adult advanced cardiovascular life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Circulation 2010; 122: 729–767.
3 Jiang L, Zhang JS. Mechanical cardiopulmonary resuscitation for patients with cardiac arrest. World J Emerg Med 2011; 2: 165–168.
4 von Planta I, Wagner O, von Planta M, Ritz R. Determinants of survival after rodent cardiac arrest: implications for therapy with adrenergic agents. Int J Cardiol 1993; 38: 235–245.
5 Deakin CD, Nolan JP, Soar J, Sunde K, Koster RW, Smith GB, et al. European Resuscitation Council Guidelines for Resuscitation 2010 Section 4. Adult advanced life support. Resuscitation 2010; 81: 1305–1352.
6 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 randomized trial. Lancet 2011; 377: 301–311.
7 Jadad AR, Moore RA, Carroll D, Jenkinson C, Reynolds DJ, Gavaghan DJ, et al. Assessing the quality of reports of randomized clinical trials:is blinding necessary? Control Clin Trials 1996; 17: 1–12.
8 Egger M, Smith GD, Douglas G. Systematic reviews in health care: meta-analysis in context. BMJ Books 2001; 2: 3–475.
9 Higgins JP, Thompson SG, Deek JJ, Altman DG. Measuring inconsistency in meta-analyses. Br Med J 2003; 327: 557–560.
10 Higgins J, Thompson S, Deeks J, Altman D. Statistical heterogeneity in systematic reviews of clinical trials: a critical appraisal of guidelines and practice. J Health Serv Res Policy 2002; 7: 51–61.
11 Tang J, Liu JL. Misleading funnel plot for detection of bias in meta-analysis. J Clin Epidemiol 2000; 53: 477–484.
12 Chen SP. Curative effects of the heart pump in 109 pre-hospital cardiopulmonary resuscitation patients for cardiopulmonary resuscitation. Chin Crit 2009; 21: 378.
13 Kulstad EB, Courtney DM, Waller D. Induction of therapeutic hypothermia via the esophagus: a proof of concept study. World J Emerg Med 2012; 3: 118–122.
14 Baubin M, Sumann G, Rabl W, Eibl G, Wenzel V, Mair P. Increased frequency of thorax injuries with ACD-CPR. Resuscitation 1999; 41: 33–38.
15 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. French Active Compression-Decompression Cardiopulmonary Resuscitation Study Group. N Engl J Med 1999; 341: 569–575.
16 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: 163–172.
17 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? Med Klin (Munich) 1997; 92: 381–388.
18 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: 955–961.
19 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. Cardiothorac Vasc Anesth 1996; 10: 178–186.
20 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: 125–134.
21 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: 1417–1423.
22 Ellinger K, Luiz T, Denz C, van Ackern K. Randomized use of an active compression-decompression technique within the scope of preclinical resuscitation. Anasthesiol Intensivmed Notfallmed Schmerzther 1994; 29: 492–500.
23 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. J Am Coll Cardiol 1994; 24: 201–209.
24 Reynolds JC, Salcido DD, Menegazzi JJ. Correlation between coronary perfusion pressure and quantitative ECG waveform measures during resuscitation of prolonged ventricular fibrillation. Resuscitation 2012; 83: 1497–1502.
25 Wang HC, Chiang WC, Chen SY. Video recording and time motion analyses of manual versus mechanical cardiopulmonary resuscitation during ambulance transport. Resuscitation 2007; 74: 453–460.
26 Eisenberg MS, Cummins RO, Damon S, Larsen MP, Hearne TR. Survival rates from out-of-hospital cardiac arrest: recommendations for uniform definitions and data to report. Ann Emerg Med 1990; 19: 1249–1259.
27 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: 684–693.
28 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. Ann Emerg Med 1995; 25: 48–51.
29 Guly UM, Mitchell RG, Cook R, Steedman DJ, Robertson CE. Paramedics and technicians are equally successful at managing cardiac arrest outside hospital. BMJ 1995; 310: 1091–1094.
30 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: 243–253.
31 Lafuente-Lafuente C, Melero-Bascones M. Active chest compression-decompression for cardiopulmonary resuscitation. Cochrane Database Syst Rev 2004; 2: CD002751.
32 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. French Active Compression-Decompression Cardiopulmonary Resuscitation Study Group. N Engl J Med 1999; 341: 569–575.

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