

Review

Efficacy and safety of active abdominal compression-decompression versus standard CPR for cardiac arrests: A systematic review and meta-analysis of 17 RCTs

Jian-Ping Wang^{a,*}, Ya-Min Zhang^b, Rong-Jia Yang^a, Ke Zhang^a, Ming-Ming Chai^a,
Dong-Chun Zhou^a

^a Emergency Department, Gansu Provincial Hospital, Lanzhou, 730000, China

^b Neurology Department, Gansu Provincial Hospital, Lanzhou, 730000, China

ARTICLE INFO

Keywords:

Active abdominal compression-decompression
Cardiopulmonary resuscitation
Cardiac arrests
Survival

ABSTRACT

Background & aim: Active abdominal compression-decompression cardiopulmonary resuscitation (AACD-CPR), which applies to cardiac arrests with contraindication of standard chest compressions (SCC) CPR, has been utilized in cardiac arrest. However, the efficacy and safety of AACD-CPR still remained controversy. This analysis was designed to comprehensively compare AACD versus SCC-CPR in patients with cardiac arrest.

Methods: We searched the Cochrane Library, PubMed, EMBASE, Web of Science and CNKI up to April 22, 2019. Mean difference (MD) and risk ratio (RR) with its 95% confidence intervals (CIs) were estimated to compare outcomes of the groups. Our primary outcomes were restoration of spontaneous circulation (ROSC) and short-term survival. Two reviewers assessed trial quality and extracted data independently. All statistical analyses were performed using standard statistical procedures provided in Review Manager 5.2 and Stata 12.0.

Results: A total of seventeen studies (N = 1647 patients) were identified for the present analysis. Compared with standard CPR, AACD-CPR was superior in restoration of spontaneous circulation (ROSC) and short-term survival, with pooled RRs of 1.38 (95% CI 1.23–1.55; $P < 0.00001$) and RRs of 2.05 (95% CI 1.69–2.50; $P < 0.00001$) respectively. In addition, significant superiority of AACD-CPR was found in incidence of fracture, long-term survival, pressure of end-tidal carbon dioxide (PETCO₂), coronary perfusion pressure (CPP) and adverse events. No significant difference was observed in incidence of vomiting.

Conclusions: Generally, in this combined analysis we found a statistically significant improvement in survival and ROSC with the use of AACD-CPR as compared with the use of standard CPR. There was also significant improvement in incidence of fracture, long-term survival, PETCO₂ and CPP with AACD-CPR in comparison with standard CPR; results were not statistically different between the groups regarding to vomiting rate and adverse events. The standardized, diversified and individualized methods of clinical operation of AACD-CPR need exploration and expectingly serve as a guideline for clinical application of AACD-CPR in the future.

1. Introduction

Cardiopulmonary resuscitation (CPR) is a series of lifesaving actions, to support and maintain breathing and circulation for an infant, child or adult who has had a cardiac or respiratory arrest, thereby improving the chances of survival [1]. Standard CPR includes the manual application of chest compressions and ventilations to patients in cardiac arrest, done in an effort to maintain viability until advanced help arrives [1,2]. This procedure is basic component of basic life support (BLS) and advanced cardiac life support (ACLS) [3,4].

According to the latest resuscitation guidelines, standard CPR cover not only the routine but also several special situations such as cardiac arrest associated with pregnancy, pulmonary embolism, asthma, anaphylaxis, morbid obesity, electrolyte imbalance, trauma, accidental hypothermia, avalanche, cardiac arrest due to drowning, electric shocks or lightning, during percutaneous coronary intervention, cardiac tamponade, cardiac surgery and cardiac or respiratory arrest due to opioid overdose or poisoning due to benzodiazepines, beta blockers, calcium channel blockers, digoxin, cocaine, cyclic antidepressants, carbon monoxide, and cyanide [3,5,6].

* Corresponding author. Emergency department, Gansu Provincial Hospital, No. 204, West Road, Dong Gang, Cheng Guan District, Lanzhou, 730000, Gansu Province, China.

E-mail address: wangcl1026@163.com (J.-P. Wang).

<https://doi.org/10.1016/j.ijss.2019.09.026>

Received 27 July 2019; Accepted 19 September 2019

Available online 24 September 2019

1743-9191/ © 2019 Published by Elsevier Ltd on behalf of IJS Publishing Group Ltd.

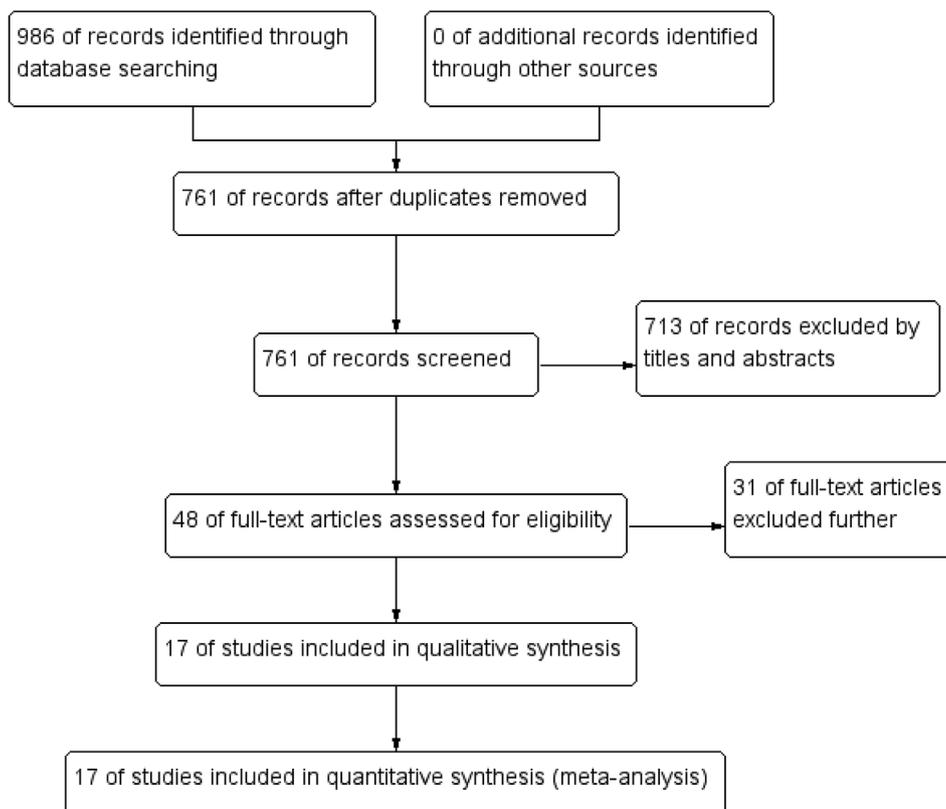


Fig. 1. Flow diagram of literature search and selection of included studies for meta-analysis.

Table 1
The characteristics of included studies for the present systematic review and meta-analysis.

Study Author	Publish year	Sample size (pts)	Male/female	Age	Outcomes	Jadad score	
Arntz HR et al.	2001	24/26	38 12	62	60	ROSC, AEs, other	5
Li JK. et al.	2014	19/21	31 9	58 ± 23	56 ± 21	ROSC, AEs, vital signs	5
Mateer JR et al.	1984	70/70				ROSC, AEs, other	4
Mateer JR et al.	1985	145/146				ROSC, AEs, other	4
Movahedi A et al.	2016	40/40	42 38	69.5 ± 1.2	65.1 ± 1.7	PETCO ₂ , ROSC, Short-term survival	4
Sack JB et al. (S)	1992	67/76	69 74	64 ± 2	63 ± 2	ROSC, AEs, Short-term survival, other	4
Sack JB et al. (I)	1992	48/55	56 47	68.3 ± 11.9	62.1 ± 15.1	ROSC, AEs, Short-term survival	5
Ward KR et al.	1989	14	12	64	65	PETCO ₂ , ROSC, Short-term survival	4
Cai M et al.	2004	35/37	41 31	40.18	39.57	ROSC, AEs, Short-term survival, vital signs	3
Dong Y et al.	2017	24/24	29 19	62.08 ± 15.57	62.08 ± 14.96	Short-term survival, incidence of fracture	4
Gu CH et al.	2015	10/10	13 7	45.2 ± 9.4	42.5 ± 9.5	CPP, PETCO ₂ , MAP, ROSC, AEs	3
Jin XY et al.	2002	25/26	29 22	41.2 ± 9.5	40.5 ± 10.5	CPP, ROSC, AEs, Short-term survival, vital signs	3
Li ZY et al.	2003	82/84	99 67	65.1 ± 11.5	65.4 ± 10.7	ROSC, AEs, Short-term survival, vital signs, SpO ₂	3
Ma CG et al.	2003	50/52	58 44	41.2 ± 11.5	65.4 ± 10.7	CPP, ROSC, AEs, Short-term survival, vital signs	3
Sha X et al.	2017	35/34	35 34	42.4 ± 9.3	45.1 ± 9.0	Short-term survival, ROSC	4
Wang GT et al.	2015	40	43			Short-term survival, ROSC	3
Zhong WQ et al.	2015	83/80	85 78	40.22 ± 9.24		ROSC, incidence of fracture	2

ROSC, restoration of spontaneous circulation; AEs, adverse events; CPP, coronary perfusion pressure; PETCO₂, pressure of end-tidal carbon dioxide; MAP, mean arterial pressure; NR, not report.

However, the standard CPR may encounter limitations in some particular cases or for some special patient with cardiac or respiratory arrest. For example, many cardiac or respiratory arrest patients accompany blowing wound or penetrating cardiac trauma, severe chest burn, flail chest, chest wall tumors, massive pleural effusion, severe pleural lesions, severe pulmonary bullae, severe pulmonary consolidation, complex congenital heart disease, severe pericardial effusion or pericardial tamponade, ruptured aortic dissection or abdominal aneurysm, esophageal or trachea rupture, thoracocytosis [7]. In addition, standard chest compressions (SCC) CPR may lead to about 30%–80% incidence of rib or sternum fractures, which always even injure pulmonary, pleural or heart and affect high quality of standard CPR. Thus,

many studies have explored and have reported a new method of CPR, active abdominal compression-decompression (AACD) CPR, which may make up for the deficiency of standard CPR [8–24]. However, the efficacy and safety of AACD-CPR still remained controversy. This analysis was designed to comprehensively compare AACD versus SCC-CPR in patients with cardiac arrest.

2. Methods and materials

2.1. Criteria for considering studies

We included studies if they meet the following criteria: a. designed

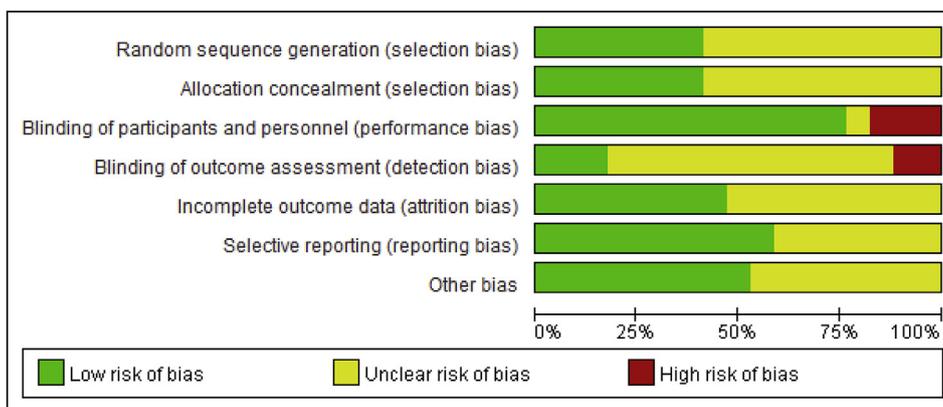


Fig. 2. Risk of bias graph: review authors' judgments about each risk of bias item presented as percentages across all included studies.

as randomized controlled trials (RCTs); b. population: adults who has had a cardiac or respiratory arrest; c. intervention: patient was rescued with AACD-CPR; d. comparison: patient was rescued with standard CPR; e. primary and secondary outcomes we defined.

Studies will be excluded if they meet the following criteria: a. experimental trials on animals or non-human studies; b. non-RCTs, cross-controlled or uncontrolled clinical trials; c. abstracts, letters, editorials, expert opinions, reviews, case reports were excluded; d. studies without sufficient data or did not meet our including criteria were excluded.

2.1.1. Definition of outcomes

- (1) Primary outcomes: restoration of spontaneous circulation; short-term survival (survival within 24 h).
- (2) Secondary outcomes: incidence of fracture; long-term survival (survival after 24 h); pressure of end-tidal carbon dioxide; coronary perfusion pressure; vomiting rate; adverse events.

2.2. Search strategy

We searched the Cochrane Library, PubMed, EMBASE, Web of Science, WanFang, CBM and CNKI to April 22, 2019. In addition, we also supplied with clinicaltrials.gov registry, Google and Baidu academic engine. Our strategy was based on combinations of medical subject headings (MeSH) and the keywords: “cardiac arrest”, “heart arrest”, “cardiopulmonary arrest”, “sudden death”, “cardiopulmonary resuscitation”, “CPR”, “heart massage”, “abdominal compression”, “abdominal lifting”, “abdominal compression”, “abdominal compression decompression”. Two assessors independently screened the titles and abstracts of each study. Once relevant studies became certain, the full texts were obtained for further evaluation. Other related references we read were also searched online for full texts and assessment, once any of them meet our including criteria, they will also be included in this meta-analysis.

2.3. Quality assessment and data extraction

Two reviewers assessed the quality of each RCT using the previously validated 5-point Jadad scale [25]. Studies with scores of 3 or more were considered high quality. In addition, the risk of bias for each studies and the risk of bias across all studies were evaluated and shown with figures generated by RevMan 5.2 software [26].

Data for the comparative analysis of AACD-CPR versus SCC-CPR for patients with cardiac or respiratory arrest were extracted independently by two reviewers, and disagreement was resolved through discussion. The extracted contents, including first authors, published years, sample size, interventions, age, quality score and outcomes of each study, were displayed using a standardized form. Data collected were input into

RevMan 5.2 and Stata 12.0 software for analysis.

2.4. Statistical analysis

The data of comparable outcomes between AACD-CPR and SCC-CPR were combined-analyzed, using the standard statistical procedures provided in RevMan 5.2 [26]. Dichotomous data were measured with risk ratio (RR) and continuous variable data were measured with mean difference (MD). The heterogeneity between studies was evaluated by the chi-square-based Q statistical test [27], with P_h value and I^2 statistic, ranging from 0% to 100%, to quantify the effect of heterogeneity. $P_h \leq 0.10$ was deemed to represent significant heterogeneity [28], and pooled RRs were estimated using a random-effect model (the DerSimonian and Laird method [29]). On the contrary, if statistical study heterogeneity was not observed ($P_h > 0.10$), a fixed effects model (the Mantel-Haenszel method [30]) was used. The effects of outcome measures were considered to be statistically significant if pooled RRs with 95% CI did not overlap with 1 or pooled MDs with 95% CI did not overlap with 0.

For the primary outcomes, we performed subgroup analysis by publish year (≤ 2010 , > 2010), Sample size (≤ 100 pts, > 100 pts), Jadad score (2 or 3, 4 or 5). Besides, for ROSC, we conducted cumulative meta-analysis of comparison between AACD-CPR and SCC-CPR sort by publish year and sample size respectively. Finally, Begg's funnel plot and Egger's publication bias plot for detecting publication bias. If the shape of funnel plots revealed no obvious evidence of asymmetry, we considered that there was no obvious publication bias. All statistical analyses were performed using standard statistical procedures provided in RevMan 5.2 and Stata 12.0.

This work has been reported in line with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [31] and Assessing the methodological quality of systematic reviews (AMSTAR) Guidelines [32].

3. Results

3.1. Included studies, study characteristics, and quality assessment

In total, 986 studies were initially identified; after duplicates were removed, the titles and abstracts of 761 studies were screened. Of these, 713 studies were excluded, and the full texts of the remaining 48 studies were obtained for further evaluation. After reading the full texts, 31 studies were excluded for various reasons such that, ultimately, 17 RCTs [8–24] (N = 1647 participants) were included in this meta-analysis (Fig. 1). Among the studies, the sample size ranged from 20 to 291 patients. Nine studies experienced a sample size of less than 100 patients and eight studies were conducted with a sample size of more than 100 patients (Table 1).

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Arntz HR, et al. 2001	?	?	+	+	+	?	+
Cai M, et al. 2004	?	?	+	?	?	+	+
Dong Y, et al. 2017	?	?	+	+	+	?	?
Gu CH, et al. 2015	?	?	+	?	+	+	+
Jin XY, et al. 2002	?	?	+	?	?	+	+
Li JK, et al. 2014	?	?	+	+	+	+	?
Li ZY, et al. 2003	?	?	+	?	?	+	+
Ma CG, et al. 2003	?	?	+	?	?	+	+
Mateer JR, et al. 1984	+	+	+	?	?	?	+
Mateer JR, et al. 1985	+	+	+	?	?	+	?
Movahedi A, et al. 2016	+	+	+	?	?	?	?
Sack JB, et al. 1992(I)	?	?	+	?	+	+	+
Sack JB, et al. 1992(S)	+	+	+	?	?	?	?
Sha X, et al. 2017	+	+	+	+	+	+	?
Wang GT, et al. 2015	+	+	+	+	+	?	?
Ward KR, et al. 1989	+	+	+	?	?	+	+
Zhong WQ, et al. 2015	?	?	?	?	+	?	?

Fig. 3. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

Graphs showing risk of bias were then generated. The overall risk of bias for each RCT is presented as a percentage relative to all included studies in Fig. 2, and the risk of individual types of bias is displayed in Fig. 3. The risk of bias graphs for the RCTs indicated generally low risk of performance bias. About half of studies experienced low risk and unclear of bias in all items respectively. Five studies experienced a high risk of performance and detection bias.

3.2. Comparison of primary outcomes between AACD and SCC-CPR

As shown in Figs. 4 and 5, compared with standard CPR, AACD-CPR was superior in ROSC, with pooled RR of 1.38 (95% CI 1.23–1.55; $P < 0.00001$). Similarly, our analysis showed that AACD-CPR may significantly improve short-term survival of cardiac or respiratory arrest patients, with pooled RR of 2.05 (95% CI 1.69–2.50; $P < 0.00001$) respectively. The pooled analysis was performed using fixed-effect models because no significant heterogeneity ($P_h > 0.1$) was detected among the studies.

3.3. Comparison of secondary outcomes between AACD and SCC-CPR

As Table 2 showing, our pooled analysis showed that compared with standard CPR, cardiac or respiratory arrest patients receiving AACD-CPR may experience less than half incidence of fracture, with pooled RR of 0.48 (95% CI: 0.30–0.77; $P = 0.002$). In long-term survival, result indicated that the survival rate in AACD-CPR group was more than twofold than standard CPR (RR 2.25; 95% CI: 1.42–3.57; $P = 0.0005$). In addition, significant superiority of AACD-CPR was also found in PETCO2 (MD 7.93; 95% CI: 7.09–8.77; $P < 0.00001$), CPP (MD 15.86; 95% CI: 11.22–20.5; $P < 0.00001$) and adverse events (RR 0.84; 95% CI: 0.70–1.00; $P = 0.05$). No significant difference was observed in incidence of vomiting, with pooled RR of 0.94 (95% CI: 0.78–1.14; $P = 0.55$).

3.4. Subgroup analysis

Subgroup analysis was conducted for comparison of AACD versus SCC-CPR regarding ROSC and short-term survival. As Table 3 showing, for ROSC, compared with SCC-CPR, AACD-CPR showed significant improvement in all of the subgroups grouped according to publish year (≤ 2010 , > 2010), sample size (≤ 100 pts, > 100 pts), and Jadad score of 4 or 5, except the subgroup of Jadad score of 2 or 3 (RR 1.25; 95% CI: 0.94–1.66; $P = 0.13$). Similarly, for short-term survival, significant advantages of AACD-CPR were observed in all subgroup analysis. The detailed results of subgroup analysis were displayed in Table 3.

3.5. Cumulative meta-analysis of ROSC between AACD and SCC-CPR

Additionally, in order to explore the research status and trend of results of this subject, we further performed cumulative meta-analysis sorting by publish year and sample size of studies respectively. As displayed in Fig. 6, cumulative meta-analysis sorting by ascending publish year showed that, from 1984 to 2017, generally, the results seemingly trended to superiority of AACD-CPR in ROSC. Cumulative meta-analysis sorting by publish year indicated that, by 2015, the pooled results approach to significant stabilization. As displayed in Fig. 7, the pooled results did not approach to stabilization as the sample size increased.

3.6. Publication bias

Begg's funnel plot and Egger's publication bias plot were conducted for assessing the publication bias of included literatures and we could roughly assess the publication bias by seeing whether their shapes were of any obvious asymmetry. According to Fig. 8 showing, no clear evidence of publication bias was observed.

4. Discussion

Cardiac arrest, as the sudden and lethality, has been a common "enemy" of human beings and a lot of manpower and money has been put into worldwide [33]. According to the cost-utility analysis from Bharmal MI in 2019 [33], the mean and median operating cost for patients undergoing CPR was \$156,263 and \$125,683 per patient (IQR

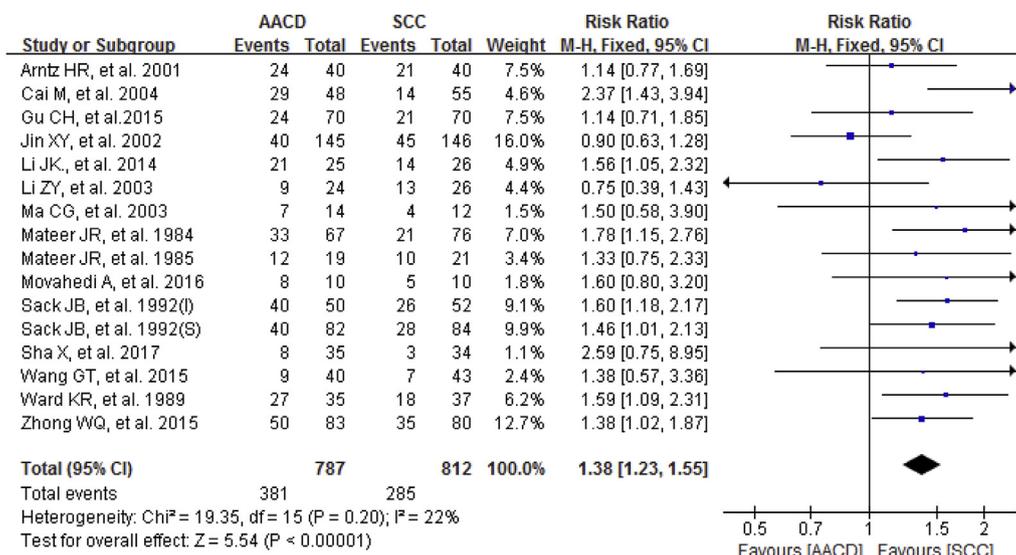


Fig. 4. Forest plot of comparison between AACD and SCC-CPR regarding to ROSC.

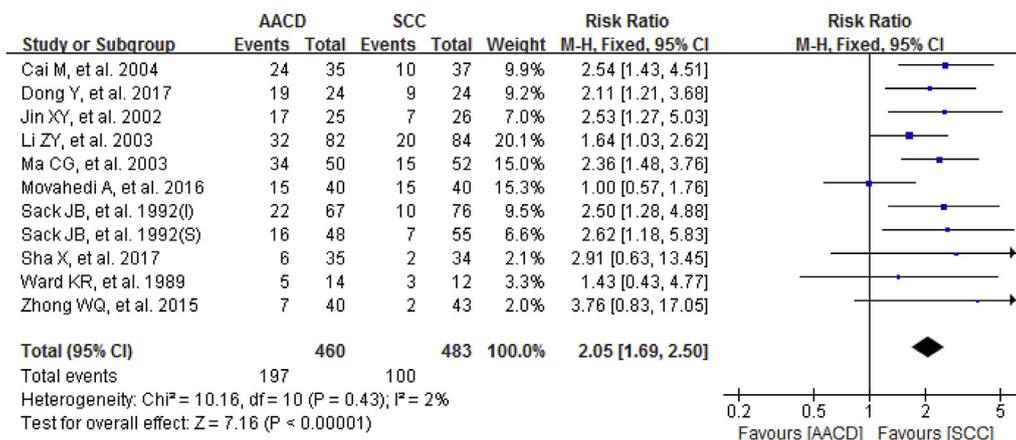


Fig. 5. Forest plot of comparison between AACD- and SCC-CPR regarding to short-term survival.

Table 2

The pooled results of secondary outcomes for the comparison of AACD-versus SCC-CPR.

Outcomes	Number of studies	Number of participants	Pooled results		
			Effect estimates	95% CI	P value
Incidence of fracture	6	487	RR 0.48	0.30, 0.77	0.002
Long-term survival	3	215	RR 2.25	1.42, 3.57	0.0005
PETCO ₂	3	126	MD 7.93	7.09, 8.77	< 0.00001
CPP	3	173	MD 15.86	11.22, 20.5	< 0.00001
Vomiting rate	6	893	RR 0.94	0.78, 1.14	0.55
Adverse events	10	1164	RR 0.84	0.70, 1.00	0.05

PETCO₂, pressure of end-tidal carbon dioxide; CPP, coronary perfusion pressure; RR, relative risk; MD, mean difference; CI, confidence intervals.

\$49,751–\$206,341 per patient), respectively. Operating costs ranged from \$9245 to \$942,681. There was significant variation in cost even among survivors, ranging from \$139,581 to \$336,698 [33]. Extracorporeal cardiopulmonary resuscitation (ECPR) is a resource-intensive tool that provides haemodynamic and respiratory support in patients who have suffered cardiac arrest. AACD-CPR technique adopts abdominal pressure cardiopulmonary resuscitation (CPR-LW100) to adsorbed on the epigastrium of patients suffering from cardiac arrest, then pull up (tension of 10–30 kg) and compress downward (pressure of 40–50 kg) the abdomen alternately and continuously with a frequency of 100 times per minute to support and maintain breathing and circulation.

The use of standardization, diversification and individualization of AACD-CPR in clinical practice lays the foundation for high quality CPR [34–37]. First, when compressing abdomen, the pressure in the abdominal cavity rises and the diaphragm moves up, rapidly producing a higher exhalation velocity to expel the airway and the foreign bodies stored in the lung, helping the patient to smooth the upper and lower respiratory tract. Second, pulling and pressing the abdomen can drive and increase reflux of arteriovenous blood, especially improves the coronary artery perfusion pressure when increasing abdominal aortic pressure. This effect could increase the cardiac output, and could establish a more effective artificial circulation.

In this study, we comprehensively compared AACD versus SCC-CPR

Table 3
Subgroup analysis of the comparison of AACD versus SCC-CPR for the primary outcomes.

Outcomes	Number of studies	Number of participants	Pooled results		
			RR	95% CI	P value
ROSC					
Publish year					
≤ 2010	10	1073	1.38	1.14, 1.68	0.001
> 2010	8	526	1.41	1.14, 1.73	0.001
Sample size					
≤ 100 pts	8	522	1.41	1.15, 1.73	0.0009
> 100 pts	8	1077	1.37	1.19, 1.57	< 0.00001
Jadad score					
2, 3	7	856	1.25	0.94, 1.66	0.13
4, 5	9	743	1.53	1.32, 1.77	< 0.00001
Short-term survival					
Sample size					
≤ 100 pts	5	465	1.77	1.38, 2.27	< 0.00001
> 100 pts	6	478	2.51	1.82, 3.45	< 0.00001
Jadad score					
2, 3	5	474	2.20	1.69, 2.85	< 0.00001
4, 5	6	469	1.88	1.40, 2.54	< 0.0001
Publish year					
≤ 2010	7	663	2.20	1.74, 2.77	< 0.00001
> 2010	4	280	1.69	1.16, 2.45	0.006

ROSC, restoration of spontaneous circulation; RR, relative risk; CI, confidence intervals.

in patients with cardiac arrest. The primary objective of our study was to assess and compare ROSC and short-term survival of both groups. Our results indicated that AACD-CPR significantly improved the survival and ROSC of patients with cardiac arrest. In addition, there was also significant improvement in incidence of fracture, long-term survival, PETCO₂ and CPP with AACD-CPR in comparison with standard CPR. In our included studies, no significant heterogeneity was found in many analyses of outcomes, and fixed-effect models were used in

pooled analysis. However, though the significant results were found in this analysis, the pooled RR of ROSC was less than 2.0. This result lacked enough difference in clinical practice. In short and long-term survival, results indicated that the survival rate in AACD-CPR group was more than twofold than standard CPR, which may indicate significant superiority of AACD-CPR in clinical practice. Patients receiving AACD-CPR may experience less than half incidence of fracture, with pooled RR of 0.48, which was reasonable and readily comprehensible. However, in spite of significant difference in PETCO₂ and CPP, there was no definition of clinical significance in the original studies. Thus, further researches and criterion were needed in the future to clear whether the distinction of our pooled results has clinical significance.

Our study had several limitations. First, the main limitation was the variation of causes of cardiac and respiratory arrests. In our included studies, the cardiac and respiratory arrests resulted from cardiogenic causes [17], pesticide poisoning [22], drowning [23], severe pneumonia [24], craniocerebral trauma and cerebrovascular disease [24]. Many studies did not report the causes of cardiac and respiratory arrests. Considering the causes of cardiac and respiratory arrests may be crucial to the prognosis of patients, this limitation may lead to any bias to the analysis results. Second, the ages of included patients varied widely. The mean ages ranged from 40 years to 60 years. However, because of the heterogeneity, we failed to conduct subgroup analysis according to age. Third, limited by the number of studies, we failed to conduct subgroup analysis to explore the efficacy of AACD versus SCC-CPR in patients with cardiac and respiratory arrests resulting from different causes.

Further studies are needed to improve basic researches, and to clear the efficacy of single AACD-CPR in patients with cardiac and respiratory arrests resulting from different causes. The application population and scope of AACD-CPR should be clear in the future. In addition, multiple, randomized clinical studies should be designed to explore the efficacy and safety of AACD-CPR, especially should focus on discharge survival and abdominal injury.

Generally, in this combined analysis we found a statistically

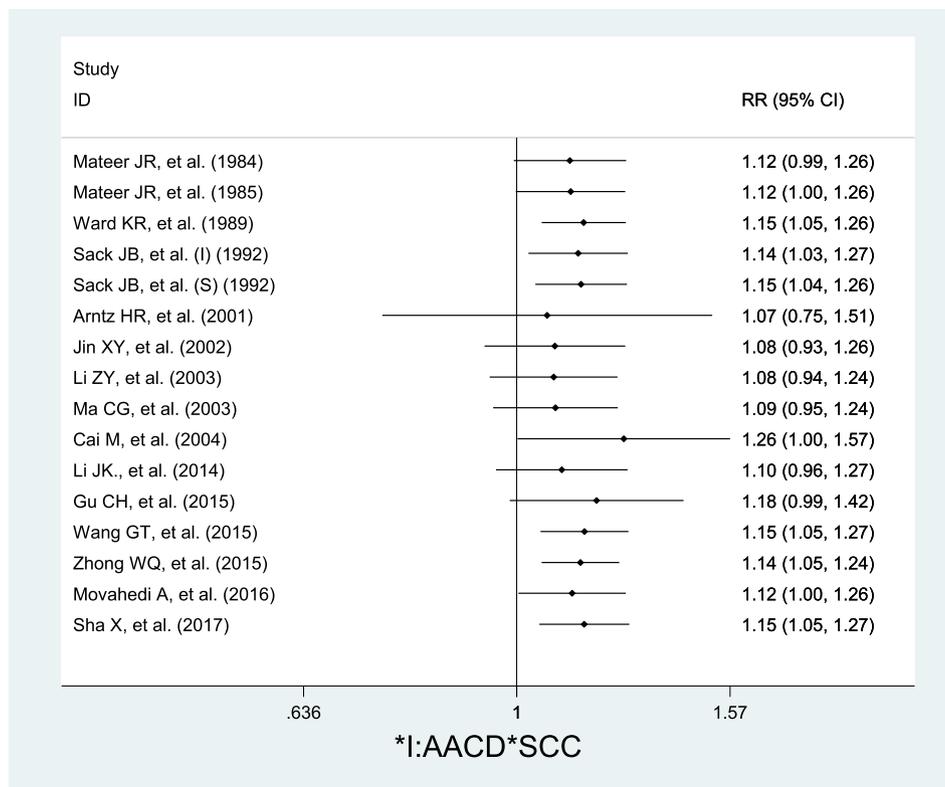


Fig. 6. Cumulative meta-analysis of ROSC between AACD- and SCC-CPR sorting by publish year.

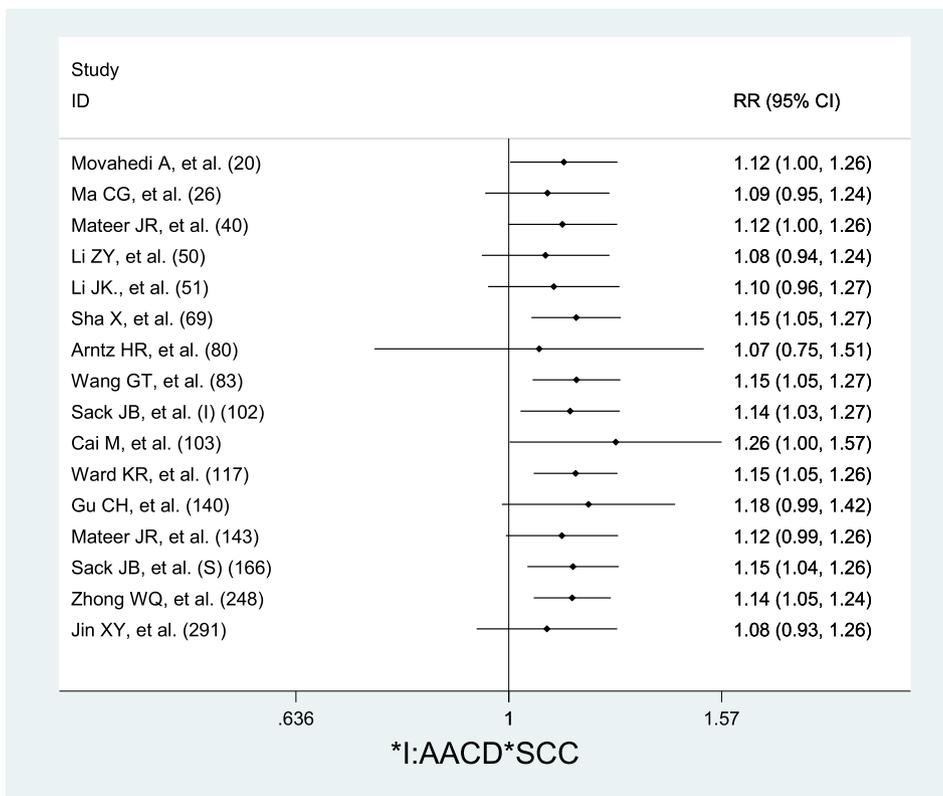


Fig. 7. Cumulative meta-analysis of ROSC between AACD- and SCC-CPR sorting by sample size.

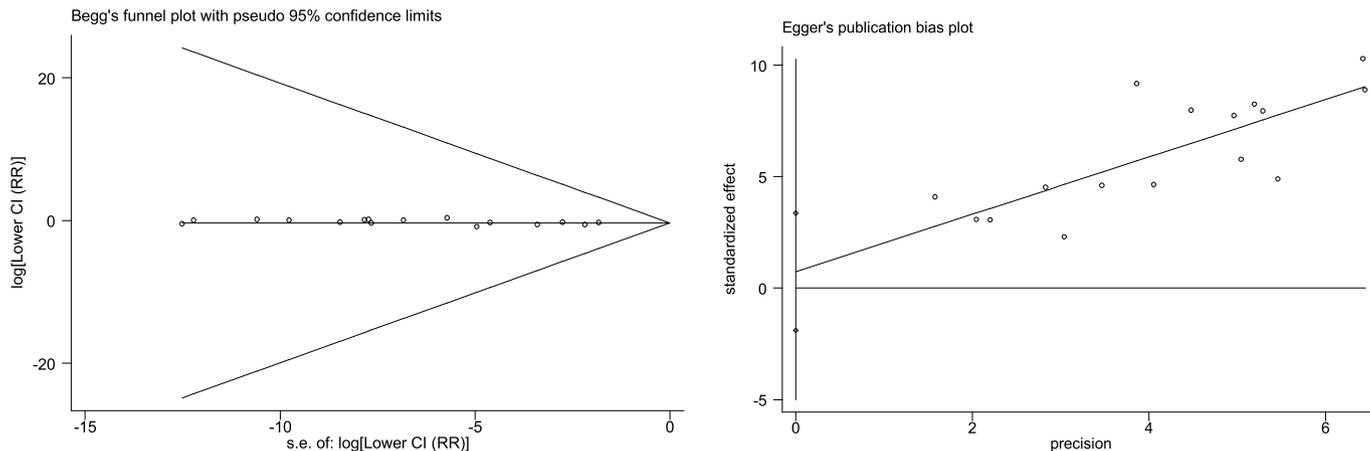


Fig. 8. Begg's funnel plot and Egger's publication bias plot for detecting publication bias.

significant improvement in survival and ROSC with the use of AACD-CPR as compared with the use of standard CPR. There was also significant improvement in incidence of fracture, long-term survival, PETCO₂ and CPP with AACD-CPR in comparison with standard CPR; results were not statistically different between the groups regarding to vomiting rate and adverse events. The standardized, diversified and individualized methods of clinical operation of AACD-CPR need exploration and expectingly serve as a guideline for clinical application of AACD-CPR in the future.

Ethical approval

Ethical Approval is not applicable.

Sources of funding

General research project of Gansu provincial people's hospital (18GSSY4-22).

Research registration unique identifying number (UIN)

The name of the registry: Research Registry, UIN: Reviewregistry720, <https://www.researchregistry.com/browse-the-registry#registryofsystematicreviewsmeta-analyses/>

Author contribution

The authors on this paper all participated in study design. All authors have read and approved this version of the article, and due care has been taken to ensure the integrity of the work. The material of this

article is original research and no part of this paper has been previously published. The material has also not been submitted for publication elsewhere while under consideration. No conflict of interest exists in the submission of this manuscript. All authors have the appropriate permissions and rights to the reported data.

Guarantor

Jian-Ping Wang.

Conflicts of interest

The authors declare no relevant conflict of interest.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Data statement

The material of this article is original research. All data in this manuscript is available and transparent for readers.

References

- [1] V. Bhatnagar, et al., Cardiopulmonary resuscitation: Unusual techniques for unusual situations, *J. Emergencies, Trauma, Shock* 11 (1) (2018) 31–37.
- [2] V.A. Beckett, M. Knight, P. Sharpe, The CAPS Study: incidence, management and outcomes of cardiac arrest in pregnancy in the UK: a prospective, descriptive study, *Bjog* 124 (9) (2017) 1374–1381.
- [3] A. Truhlar, et al., European resuscitation council guidelines for resuscitation 2015: Section 4. Cardiac arrest in special circumstances, *Resuscitation* 95 (2015) 148–201.
- [4] J.M. Mhyre, et al., Cardiac arrest during hospitalization for delivery in the United States, 1998–2011, *Anesthesiology* 120 (4) (2014) 810–818.
- [5] J.M. Field, Update on cardiac resuscitation for sudden death: International guidelines 2000 on resuscitation and emergency cardiac care, *Curr. Opin. Cardiol.* 18 (1) (2003) 14–25.
- [6] P.B. Sherren, et al., Algorithm for the resuscitation of traumatic cardiac arrest patients in a physician-staffed helicopter emergency medical service, *Crit. Care* 17 (2) (2013) 308.
- [7] Cardiopulmonary Resuscitation Specialized Committee Of Chinese Research Hospital, A, et al., [Chinese expert consensus on cardiopulmonary resuscitation guidelines for the operation of active abdominal compression-decompression cardiopulmonary resuscitation], *Zhonghua Wei Zhong Bing Ji Jiu Yi Xue* 31 (4) (2019) 385–389.
- [8] H.R. Arntz, et al., Phased chest and abdominal compression-decompression versus conventional cardiopulmonary resuscitation in out-of-hospital cardiac arrest, *Circulation* 104 (7) (2001) 768–772.
- [9] J.K. Li, J. Wang, T.F. Li, Interposed abdominal compression-cardiopulmonary resuscitation after cardiac surgery, *Interact. Cardiovasc. Thorac. Surg.* 19 (6) (2014) 985–989.
- [10] J.R. Mateer, et al., Interposed abdominal compression CPR versus standard CPR in prehospital cardiopulmonary arrest: preliminary results, *Ann. Emerg. Med.* 13 (9 Pt 2) (1984) 764–766.
- [11] J.R. Mateer, et al., Pre-hospital IAC-CPR versus standard CPR: paramedic resuscitation of cardiac arrests, *Am. J. Emerg. Med.* 3 (2) (1985) 143–146.
- [12] A. Movahedi, et al., A comparison of the effect of interposed abdominal compression cardiopulmonary resuscitation and standard cardiopulmonary resuscitation methods on end-tidal CO₂ and the return of spontaneous circulation following cardiac arrest: a clinical trial, *Acad. Emerg. Med.* 23 (4) (2016) 448–454.
- [13] J.B. Sack, M.B. Kesselbrenner, D. Bregman, Survival from in-hospital cardiac arrest with interposed abdominal counterpulsation during cardiopulmonary resuscitation, *Jama* 267 (3) (1992) 379–385.
- [14] J.B. Sack, M.B. Kesselbrenner, A. Jarrad, Interposed abdominal compression-cardiopulmonary resuscitation and resuscitation outcome during asystole and electromechanical dissociation, *Circulation* 86 (6) (1992) 1692–1700.
- [15] K.R. Ward, et al., A comparison of interposed abdominal compression CPR and standard CPR by monitoring end-tidal PCO₂, *Ann. Emerg. Med.* 18 (8) (1989) 831–837.
- [16] M. Cai, Q. Li, S.J. Wu, [A comparative study on two different CPR in cerebral resuscitation of patients with cardiac arrest], *Chin. Nurs. Res.* (07) (2004) 571–572.
- [17] Y. Dong, Y.Q. Liu, J. Du, S.W. Jiang, J.X. Fu, [The clinical effects of two methods of cardiopulmonary resuscitation with orotracheal intubation in patients with sudden cardiac death], *Tianjin Journal of Nursing* 25 (06) (2017) 503–505.
- [18] C.H. Gu, Y.F. Shi, L.X. Wang, K.X. Liu, Y.L. Wang, [Effect of interposed abdominal pulling-pressing cardiopulmonary resuscitation for patients with cardiac arrest], *Chinese Journal of Disaster Medicine* 3 (11) (2015) 611–614.
- [19] X.Y. Jin, Z.P. Zhang, D.H. Zhang, M.L. Wang, C.M. Zhang, [A controlled study of interposed abdominal compression CPR and standard CPR in PatientsWith cardiac arrest], *J. Henan Univ.* (04) (2002) 6–8.
- [20] Z.Y. Li, T. Yang, X.G. Hu, Z.J. Sun, J.Q. Chen, [Effects of chest - abdominal compression CPR on the survival rate of patients with sudden death], *Chin. Crit. Care Med.* (05) (2003) 307–308.
- [21] C.G. Ma, C.S. Huangpu, [Application of insertion abdominal compression in cardiopulmonary resuscitation], *Chin. J. Emerg. Med.* (09) (2003) 72–73.
- [22] X. Sha, S.L. Zhang, L.X. Wang, et al., [Effects of abdominal elevation CRP on oxygen metabolism and prognosis in patients with cardiac arrest], *Chinese critical care emergency medicine* 29 (12) (2017) 1117–1121.
- [23] G.T. Wang, S.L. Zhang, LiuQ, et al., [Clinical application of cardiopulmonary resuscitation with abdominal lift: a report of 40 case], *Chin. J. Emerg. Med.* 24 (11) (2015) 1264–1267.
- [24] W.Q. Zhong, Y.M. Li, L.Z. Deng, [Application analysis of abdominal pressure lifting device in 83 patients with cardiopulmonary resuscitation], *Internal Medicine of China* 10 (04) (2015) 508–509.
- [25] W.G. Clark HD, C. Huët, F.A. McAlister, L.R. Salmi, D. Fergusson, A. Laupacis, Assessing the quality of randomized trials: reliability of the Jadad scale, *Constr. Clin. Trials* 20 (5) (1999) 448–452.
- [26] Review Manager (RevMan) [Computer Program]. Version 5.2, The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, 2012.
- [27] J. Lau, J.P. Ioannidis, C.H. Schmid, Quantitative synthesis in systematic reviews, *Ann. Intern. Med.* 127 (9) (1997) 820–826.
- [28] University of York Centre for Reviews and Dissemination, Systematic Reviews: CRD's Guidance for Undertaking Reviews in Health Care, CRD, University of York, York, 2009.
- [29] R. DerSimonian, N. Laird, Meta-analysis in clinical trials revisited, *Contemp. Clin. Trials* 45 (Pt A) (2015) 139–145.
- [30] N. Mantel, W. Haenszel, Statistical aspects of the analysis of data from retrospective studies of disease, *J. Natl. Cancer Inst.* 22 (4) (1959) 719–748.
- [31] D. Moher, et al., Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement, *Bmj* 339 (2009) b2535.
- [32] B.J. Shea, et al., Amstar 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both, *Bmj* 358 (2017) j4008.
- [33] M.I. Bharmal, et al., Cost-utility of extracorporeal cardiopulmonary resuscitation in patients with cardiac arrest, *Resuscitation* 136 (2019) 126–130.
- [34] L.X. Wang, Initiation of the “abdominal pump” research of cardiopulmonary resuscitation by increasing intra-abdominal pressure [J], *Med J Chin PLA* 39 (10) (2014) 767–770.
- [35] L.X. Wang, Y.H. Liu, M.H. Zhou, et al., Effects of subdiaphragmatic cardiac compression on cardiac arrest during liver transplantation, *Chin Med J (Engl)* 125 (12) (2012) 2228–2230.
- [36] M. Li, W. Song, Y.H. Ouyang, et al., Clinical evaluation of active abdominal lifting and compression CPR in patients with cardiac arrest, *Am. J. Emerg. Med.* 35 (12) (2017) 1892–1894.
- [37] T. Yu, Implementation of high quality cardiopulmonary resuscitation: from guidelines to practice, *Chin. J. Emerg. Med.* 24 (1) (2015) 17–21.