Effect of real-time feedback on patient's outcomes and survival after cardiac arrest
A systematic review and meta-analysis

Guang Wei Lv, MD[a], Qing Chang Hu, MD[a], Meng Zhang, MD[a], Shun Yi Feng, MD[a], Yong Li, MD[a], Yi Zhang, MBBS[b], Yuan Yuan Zhang, MBBS[c], Wen Jie Wang, MD[a],* iD

Abstract

Purpose: This study investigated the effect of real-time feedback on the restoration of spontaneous circulation, survival to hospital discharge, and favorable functional outcomes after hospital discharge.

Methods: PubMed, ScienceDirect, and China National Knowledge Infrastructure databases were searched to screen the relevant studies up to June 2020. Fixed-effects or random-effects model were used to calculate the pooled estimates of relative ratios (RRs) with 95% confidence intervals (CIs).

Results: Ten relevant articles on 4281 cardiac arrest cases were identified. The pooled analyses indicated that real-time feedback did not improve restoration of spontaneous circulation (RR: 1.13, 95% CI: 0.92–1.37, and $P = .24$; $I^2 = 81\%$; $P < .001$), survival to hospital discharge (RR: 1.27, 95% CI: 0.90–1.79, and $P = .18$; $I^2 = 74\%$; $P < .001$), and favorable neurological outcomes after hospital discharge (RR: 1.09, 95% CI: 0.87–1.38; $P = .45$; $I^2 = 16\%$; $P = .31$). The predefined subgroup analysis showed that the sample size and arrest location may be the origin of heterogeneity. Begg's and Egger's tests showed no publication bias, and sensitivity analysis indicated that the results were stable.

Conclusion: The meta-analysis had shown that the implementation of real-time audiovisual feedback was not associated with improved restoration of spontaneous circulation, increased survival, and favorable functional outcomes after hospital discharge.

Abbreviations: CI = confidence interval, CPR = cardiopulmonary resuscitation, IHCA = in-hospital cardiac arrest, OHCA = out-of-hospital cardiac arrest, RR = relative ratio.

Keywords: cardiac arrest, chest compression, feedback

1. Introduction

Chest compressions are an essential part of efficient cardiopulmonary resuscitation (CPR). Early implementation of high-quality chest compressions reduces mortality and improves favorable neurological outcomes.[1,2] High-quality chest compressions depend on appropriate rate and depth, full chest recoil, and minimal interruptions during chest compressions. However, numerous studies have demonstrated poor compliance with the recommended targets and wide variability in the quality of CPR in clinical practice.[3–5]

Real-time audiovisual feedback technology can provide information about the quality of chest compression components during training and in clinical practice, thus enhancing chest compression performance to meet the guidelines. In addition, training using a mannequin equipped with a computer-based real-time audiovisual feedback system improves the retention of CPR skills.[6]

Although real-time feedback was associated with greater ability to maintain high-quality chest compressions in simulation studies, the effect of real-time feedback on patient outcomes and survival after cardiac arrest remained controversial.[7,8] Several articles reported the effect of real-time feedback on patient outcomes and survival after cardiac arrest, but they varied in study designs, recruitment, and exclusion criteria and measurements.[9–18] Therefore, this study systematically evaluated the efficacy of feedback on patient outcomes and survival after cardiac arrest to provide an optimal plan for resuscitation.

[a] Emergency Department, Cangzhou Central Hospital, Cangzhou City, China, [b] Pediatric Department, Cangzhou Central Hospital, Cangzhou City, China, [c] Nursing Department, Cangzhou Infectious Disease Hospital, Cangzhou City, China.

*Correspondence: Wen Jie Wang, Emergency Department, Cangzhou Central Hospital, No. 16 Xinhua Road, Yunhe Qu, Cangzhou City 061000, China (e-mail: wwj15931761558@hotmail.com).

2. Methods

2.1. Study design

This study was performed in accordance with the preferred reporting items for systematic reviews[19] and registered it in PROSPERO (CRD42020198279). Ethical approval and informed consent of patients are not required because this study was based on published studies and did not involve patients directly.

2.2. Literature search

PubMed, ScienceDirect, and China National Knowledge Infrastructure databases were searched to screen the relevant studies up to June 2020. The following keywords were used: "feedback" and "cardiac arrest" or "resuscitation." In addition, we manually scanned the reference lists of several relevant reviews to select additional studies.

All included studies should meet the following criteria: evaluated the effect of feedback on the quality of chest compression; contained sufficient data for the assessment of relative ratios (RRs) with 95% confidence intervals (CIs). The exclusion criteria were as follows: duplicate reports, conference reports, theses, review papers, or animal studies and posters; repeated or overlapping publications.

2.3. Data extraction and quality assessment

Two reviewers independently performed data extraction from all the eligible publications using a redesigned form. The extracted information included the following: first author, year of publication, study design, study country, sample size, arrest location such as out-of-hospital cardiac arrest (OHCA) or in-hospital cardiac arrest (IHCA), monitoring equipment, and CPR providers. If the required data were missing, we attempted to contact the literature authors to ensure the accuracy of relevant information. Any disagreement was resolved by discussion or by consultation with a third author.

The quality of included studies was assessed using the Cochrane risk of bias tool for randomized controlled trials and Newcastle–Ottawa Scale for observational studies. All differing views was resolved by a third reviewer through discussion.

2.4. Statistical analysis

All statistical analyses were carried out using the Stata version 14 (StataCorp., College Station, TX), and the significance threshold was a 2-sided $P < .05$. The dichotomous variables were odds ratios with 95% CIs as effect indicators. Heterogeneity among the studies was tested by I^2 statistic percentages and the Cochran Q chi-squared test. A random-effects model was used when $P < .05$ and $I^2 > 50\%$; otherwise, a fixed-effect model was applied. Subgroup analysis was used to explore the sources of heterogeneity. Sensitivity analysis was conducted to examine the robustness and stability of study findings. Publication and selection bias were investigated through funnel plots.

3. Results

3.1. Literature search

Figure 1 shows the specific procedure of article selection. In total, 2495 studies were searched for evaluation initially. After scanning the titles and abstracts, 104 duplicate and 2375 unrelated studies were excluded. The full texts of the remaining 16 articles were read, and 10 articles were finally enrolled in this meta-analysis.[9–18]

3.2. Characteristics of the included studies and quality assessment

Table 1 presents the characteristics of the included studies. Four studies were conducted in North America,[9,10,12,14] 4 in Europe,[11,15–17] and 2 in Asia.[13,18] Among the 10 studies, 9 reported the incidence of restoration of spontaneous circulation,[9–14,16–18] 9 assessed the rate of survival to discharge,[9–15,17,18] and 4 investigated the neurological outcomes after hospital discharge.[10,11,14,17] Quality assessment was performed based on the Cochrane risk of bias tool for randomized controlled trials. The Newcastle–Ottawa Scale results for the observational studies are presented in Tables S1–S3, Supplemental Digital Content 1, http://links.lww.com/MD/H253.

3.3. Restoration of spontaneous circulation

Heterogeneity ($I^2 = 81\%$, $P < .001$) was revealed in the 9 studies,[9–14,16–18] and in the random effects model, real-time feedback did not improve restoration of spontaneous circulation (RR: 1.13, 95% CI: 0.92–1.37; $P = .24$; Fig. 2A).

3.4. Survival to hospital discharge

Nine studies that enrolled 4077 patients evaluated the association of real-time feedback with survival to hospital discharge in cardiac arrest.[9–15,17,18] The forest plot with a random-effects model ($I^2 = 74\%$, $P < .001$) indicated that real-time feedback was not associated with survival to hospital discharge (RR: 1.27, 95% CI: 0.90–1.79; $P = .18$; Fig. 2B).

3.5. Favorable neurological outcome after hospital discharge

No evident heterogeneity ($I^2 = 16\%$; $P = .31$) was observed among the 4 studies.[10,11,14,17] The result obtained with a fixed-effect model indicated that real-time feedback was not associated with favorable neurological outcome after hospital discharge (RR: 1.09, 95% CI: 0.87–1.38; $P = .45$; Fig. 2E).

4. Subgroup analysis

Subgroup analysis was performed based on the severity of sample size and arrest location to identify the possible sources of
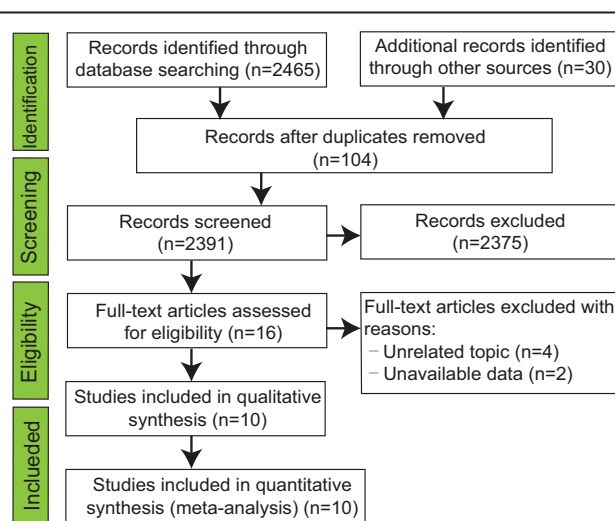

Figure 1. Summary of the study selection process.

Table 1

Characteristics of the included studies.

Author (Year)	Study country	Study design	Sample size	Arrest location	Monitoring equipment	CPR providers
Abella et al, 2007	USA	Historical case-control study	156	IHCA	Laerdal QCPR	Hospital resuscitation team
Bobrow et al, 2013	USA	Prospective cohort study	484	OHCA	ZOLL E Series Defibrillator	Emergency medical technician
Couper et al, 2015	United Kingdom	Prospective cohort study	291	IHCA	Phillips MRx QCPR defibrillator	Emergency medical technician
Crowe et al, 2015	USA	Prospective cohort study	101	IHCA and OCHA	ZOLL R Series Defibrillator	Clinicians
Goharani et al, 2019	Iran	Randomized controlled study	900	IHCA	Cardio first angel	Hospital resuscitation teams
Hostler et al, 2011	USA and Canada	Randomized controlled study	1586	OCHA	Philips MRx QCPR defibrillator	Emergency medical service providers
Kramer-Johansen et al, 2006	Norway, Sweden, and UK	Prospective cohort study	241	OCHA	Laerdal QCPR	Emergency medical service providers
Lakomek et al, 2020	Germany	Prospective cohort study	198	OCHA	corpuls3 defibrillator	Emergency medical service providers
Sainio et al, 2013	Finland	Prospective cohort study	185	OCHA	Philips MRx QCPR defibrillator	Helicopter emergency medical service providers
Vahedian-Azimi et al, 2020	Iran	Randomized controlled study	22	IHCA	Cardio first angel	ICU nurses

CPR = cardiopulmonary resuscitation, ICU = intensive care unit, IHCA = in-hospital cardiac arrest, OHCA = out-of-hospital cardiac arrest.
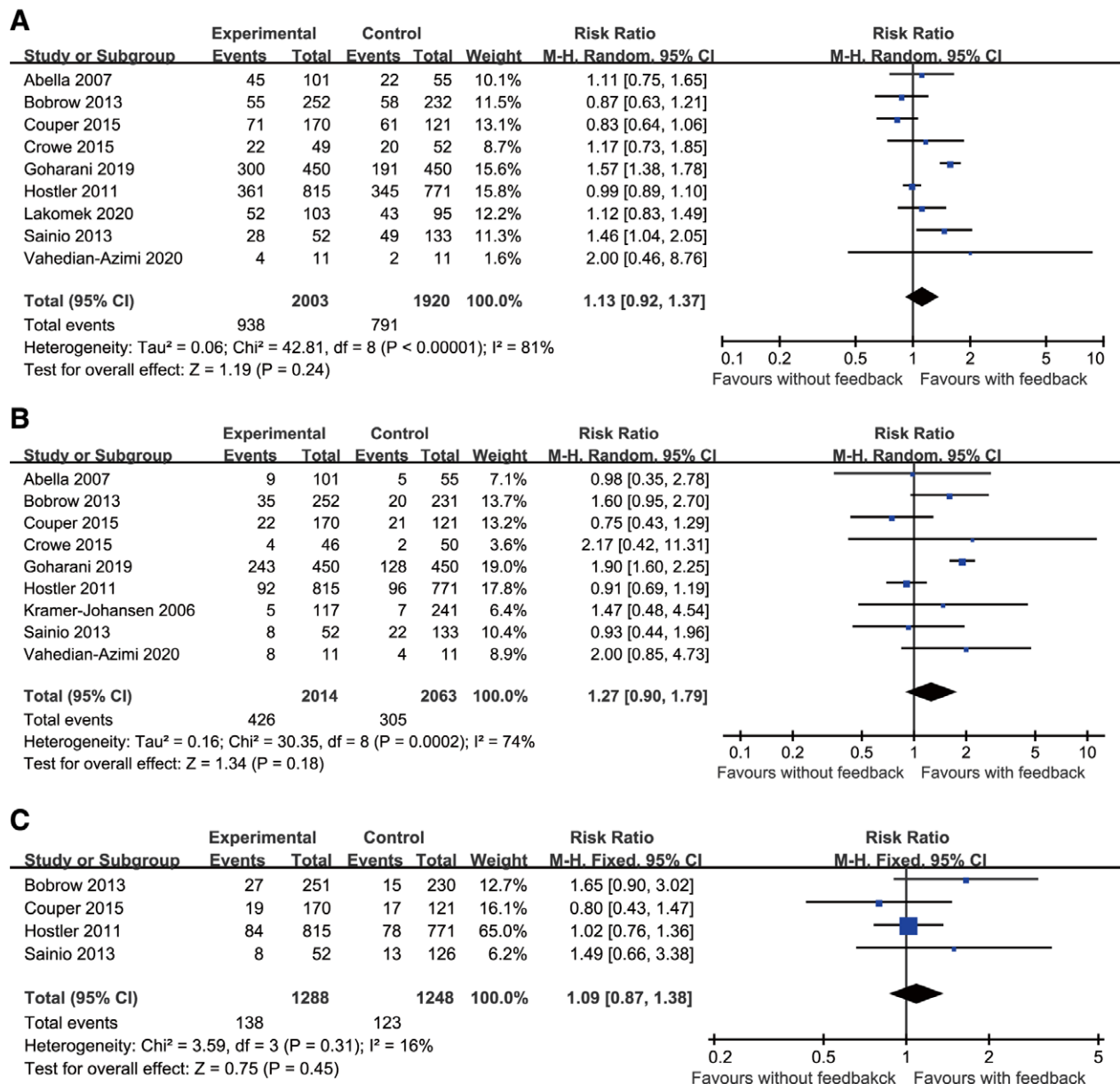
Figure 2. Forest plot of studies reporting (A) restoration of spontaneous circulation, (B) survival to hospital discharge, and (C) favorable neurological outcomes after hospital discharge.

Table 2

Subgroup analysis.

	Heterogeneity factors		No. of studies	RR (95% CI)	P value	I² (P value)
For ROSC	Sample size	≥400	3	1.12 (0.78 – 1.62)	.532	94.0% (<.001)
		<400	6	1.11 (0.91 – 1.35)	.323	39.5% (.142)
	Arrest location	OHCA	3	0.99 (0.90 – 1.09)	.868	0.0% (.541)
		OHCA/IHCA	6	1.23 (0.93 – 1.62)	.151	77.2% (.001)
For survived to hospital discharge	Sample size	≥400	3	1.40 (0.82 – 2.40)	.222	90.6% (<.001)
		<400	6	1.05 (0.74 – 1.48)	.785	0.0% (.432)
	Arrest location	OHCA	4	1.09 (0.80 – 1.49)	.591	27.2% (.247)
		OHCA/IHCA	5	1.39 (0.84 – 2.30)	.205	65.3% (.021)

CI = confidence intervals, IHCA = in-of-hospital cardiac arrest, OHCA = out-of-hospital cardiac arrest, ROSC = restoration of spontaneous circulation, RR = relative ratio.

heterogeneity (Table 2). Sample size and arrest location were causes of heterogeneity in the subgroup analysis.

5. Sensitivity analysis and publication bias

To further confirm the robustness of the results, we conducted a sensitivity analysis, but no significant changes were observed in the outcomes (Fig. 3). Begg's and Egger's tests showed no publication bias for restoration of spontaneous circulation (P = .175, Fig. 4A; P = .873, Fig. 4B), survival to hospital discharge (P = .602, Fig. 4C; P = .404, Fig. 4D), and favorable neurological outcome after hospital discharge (P = 1.00, Fig. 4C; P = .558, Fig. 4F).

6. Discussion

The current systematic review and meta-analysis present the most recent and updated work summarizing the evidence for clinical outcomes with real-time feedback during chest compression. The meta-analysis had shown that implementation of real-time audiovisual feedback device was not associated with improved restoration of spontaneous circulation, increased survival, and favorable functional outcomes after hospital discharge, consistent with the results of a prior meta-analysis.[7]

Contrary to our findings, 2 previous studies demonstrated that real-time feedback was associated with improved CPR quality, increased survival, and favorable functional outcomes.[10,13] The observed effect of real-time feedback was verified, but they were caused by factors external to the interventions. First, the implementation of unfamiliar compression feedback device required training by a clinical resuscitation provider for its usage. We cannot rule out the possibility of feedback-off to feedback-on training effect, especially in a before-after study. Second, compression feedback device studies are blind to clinical resuscitation providers. Awareness of the monitoring of chest compression performance might have resulted in better effect than the actual results obtained without supervision.

The current guidelines[20,21] thus underline the importance of ensuring the adequate compression depth and fraction of time with active chest compression, because these factors are expected to lead to better hemodynamic perfusion and thus improve the patient outcomes.[22,23] A cluster randomized trial conducted by the Resuscitation Outcomes Consortium demonstrated that the use of real-time audiovisual feedback improved the mean compression depth by 2 mm and the chest compression fraction from 64% to 66%.[14] Thus, real-time audiovisual feedback induces changes in chest compression performance that may be extremely small to increase the chances of successful resuscitation.

Kramer–Johansen et al[15] reported the mostly positive rescuer comments on real-time feedback device; 89/103 (86%) of rescuers indicated that the device helped them perform CPR better. However, 18% of the CPR providers turned off the acoustic feedback because it was "distracting." The psychological effects

involved in CPR feedback are wide-ranging. Thus, the real-time feedback device must not be extremely complex.[24]

Notably, current scientific evidence alone is insufficient to support the complete abolition of the real-time feedback device. In a crowded setting of a cardiac arrest incident, the screen may be out of sight of the chest compression providers. Similarly, in the noisy setting of sudden emergency, the audio feedback information may not be heard by chest compression providers. In addition, we have limited knowledge about the effect of real-time feedback devices on mechanical injury, such as rib fractures, cardiac rupture, and hemopneumothorax, given the lack of reports in the included studies. Assessment of the capability of these real-time devices to improve patient outcomes should
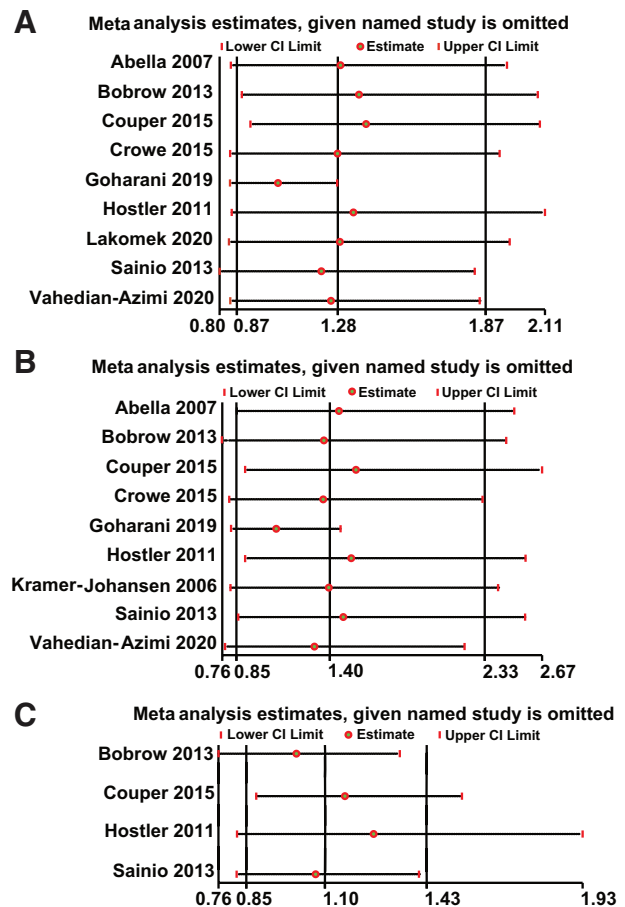
Figure 3. Sensitivity analysis of pooled hazard ratios. (A) Restoration of spontaneous circulation, (B) survival to hospital discharge, and (C) favorable neurological outcomes after hospital discharge.
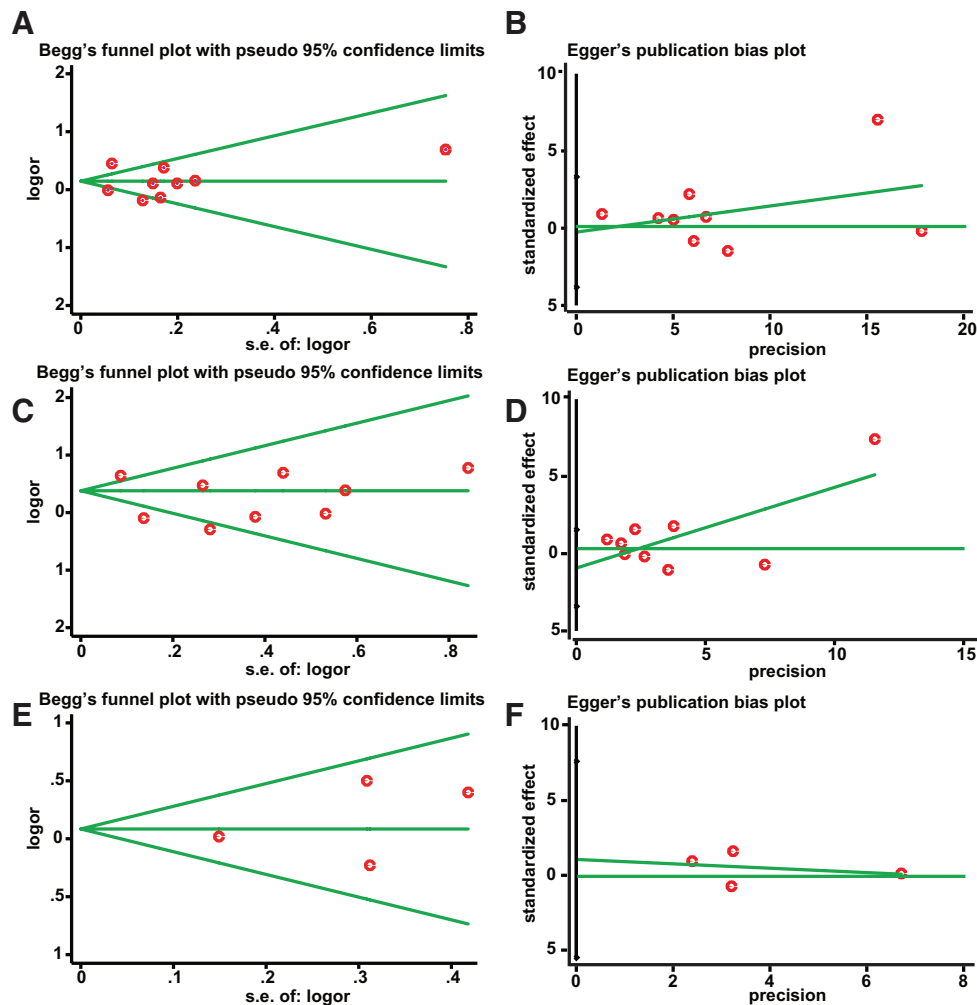
Figure 4. Funnel plot of publication bias. (A) Restoration of spontaneous circulation, (B) survival to hospital discharge, and (C) favorable neurological outcomes after hospital discharge.

be withheld until the results of large randomized controlled trials become available.

Combining studies from different populations and backgrounds may have caused in some heterogeneity observed in this current meta-analysis. Specifically, this heterogeneity came from the OHCA/IHCA subgroup, which involved both patients who experienced IHCA or OHCA. The outcome of IHCA in general wards may differ from OHCA given the different clinical characteristics of these patient populations. In addition, small study effect has been reported earlier in the form of a larger and conforming association being reported in studies with smaller sample size, and increasing the sample size may produce different results. Although the heterogeneity existed between studies, the sensitivity analysis demonstrated that the results of our meta-analysis were stable.

Several limitations of our study should be mentioned. First, several small-sample-size studies were inevitably included in our analysis, which affected the credibility of the results. Second, the pooled data might be argued because all studies published in English. Third, all the studies were based on adult cardiac arrest. Although adult chest anatomy is similar to that of children, it is not exactly the same. Fourth, investigation of mechanical complications induced by chest compression should be encouraged.

7. Conclusion

Real-time feedback device does not ultimately translate to improved patient outcomes and survival after cardiac arrest.

Certain doubts remain about the rationality of introducing such a system to clinical practice.

Author contributions

Conceptualization: Guang Wei Lv, Yong Li, Wen Jie Wang.
Data curation: Meng Zhang, Yi Zhang, Yuan Yuan Zhang.
Software: Shun Yi Feng.
Writing – original draft: Guang Wei Lv.
Writing – review & editing: Qing Chang Hu, Yong Li, Wen Jie Wang.

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