

# Video-assisted Bystander Cardiopulmonary Resuscitation Improves the Quality of Chest Compressions during Simulated Cardiac Arrests: A Systemic Review and Meta-Analysis

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## Research Article

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## Abstract

## Background

It remains unclear whether video aids can improve the quality of bystander CPR. Therefore, we summarized the simulation-based studies aiming at improving bystander CPR associated with the quality of chest compressions and time-related quality parameters.

## Methods

The systematic review was conducted according to the PRISMA guidelines. All relevant studies were searched through PubMed, Embase, Medline and Cochrane Library databases. The risk of bias was evaluated using the Cochrane collaboration tool.

## Results

A total of 259 studies were eligible for inclusion, and 6 RCT studies were ultimately included. Meta-analysis results indicated that V-CPR was significantly associated with the improved mean chest compression rate [OR = 0.66 (0.49–0.82),  $P < 0.001$ ] and the proportion of chest compressions with correct hand positioning [OR = 1.63 (0.71–2.55),  $P < 0.001$ ]; However, the difference in mean chest compression depth was not statistically significant [OR = 0.18 (-0.07–0.42),  $P = 0.15$ ], and V-CPR was not associated with the time to first chest compression compared to T-CPR [OR = -0.12 (-0.88–0.63),  $P = 0.75$ ].

## Conclusion

Video real-time guidance by dispatcher can improve the quality of bystander CPR to a certain extent. However, the quality is still not ideal, and there is a lack of guidance caused by poor video signal or inadequate interaction.

## Introduction

Although the likelihood of survival to cardiac arrest (CA) is increasing, CA has emerged as the leading cause of death worldwide(1, 2). A meta-analysis showed that the aggregate survival rate of out-of-hospital cardiac arrest (OHCA) was only 7.6%, which remained stable over the past 30 years(3). Immediate cardiopulmonary resuscitation (CPR) is the most effective measure to improve the prognosis of patients with CA(4). Studies have shown that the first witness's CPR can double the survival rate of patients with OHCA(5). Generally, the patient's family members are most likely to witness the occurrence of CA, and they are more willing to perform CPR on the spot. However, most CA witnesses are lacking life support knowledge, and have not received any CPR training. Thus, they are no able to perform on-site CPR for patients with CA. The effective way to fill such shortcomings is that the dispatcher who receives emergency calls should guide the witnesses to perform CPR on the spot by telephone, that is, the dispatcher uses telephone or video facilities to improve dispatcher-assisted CPR(DA-CPR).

DA-CPR has been widely carried out in European and American countries(6). It has been proven that DA-CPR can increase the quality of CPR performed by the first witnesses(7) and improve the survival rate of victims with CA(8, 9). In 2015, the American Heart Association (AHA) included DA-CPR in the guidelines for cardiopulmonary resuscitation for the first time(10). Many emergency medical service systems have established verbal CPR instructions to help callers cope with CPR. However, the quality of DA-CPR is still not ideal(11, 12). Although many efforts have been made to improve the quality of DA-CPR by modifying the command protocol, its actual effect is still not satisfactory(13–16).

The communication method of DA-CPR guidance is usually based on voice and telephone guidance. As a result, the quality of CPR performed by bystanders cannot be intuitively controlled, and a low-quality CPR is more likely to occur. Low-quality CPR may not improve the prognosis of patients with CA. Therefore, improving the quality of bystander CPR has become a focus of attention in recent years. With the advancement of wireless telecommunications, the introduction of video phones enables simultaneous voice and video commands. Video guidance via mobile phones can be a powerful tool for CPR guidance in emergency situations. For example, bystanders call CPR guidance and receive real-time voice instructions and video demonstrations via mobile phones, such as video self-learning programs. At the same time, the CPR performance of bystanders can be monitored and fed back by the dispatcher. Some preliminary studies have evaluated the possibility of applying video link instructions to improve the quality of bystander CPR (17), and the effect of video-assisted CPR (V-CPR) training has been extensively studied. Video self-learning procedures or video-based instructions have been documented to have more or at least as effective CPR training than conventional training methods (18–24). However, outcomes associated with V-CPR during simulated CAs remain unclear and await further study.

To address this issue, we conducted systematic review and meta-analysis of quantitative studies reporting on the effectiveness of video-assisted and telephone-assisted CPR in increasing chest compression rates during simulated CAs. The outcomes of training programs aimed at improving bystander CPR including the quality of chest compressions and time-related quality parameters were analyzed in this study.

## Materials And Methods

## Inclusion and exclusion criteria

To answer the PICOS question, the inclusion criteria for our systematic review were as follows:

1. P: Subjects were adult volunteers or high school students, without any previous CPR training.
2. I: Intervention is dispatcher initiated standardized video-guided CPR.
3. C: Control group is dispatcher initiated standardized telephone-guided CPR.
4. O: Outcome indicators were: (i) The quality of chest compressions, including the mean compression rate, the number of subjects who performed an adequate compression rate, the mean compression depth, the number of subjects who performed an adequate compression depth, and adequate positioning of hands. (ii) Time-related quality parameters, including time to initiate continuous compressions, and total hands-off time (the pause between compressions longer than 1.5 s).
5. S: Research design is randomized simulation-based studies. We did not consider articles published in non-English journals, repetitive publications, no relevant outcome indicators, and unavailable or incomplete original data.

## Literature search strategy

We searched PubMed, EMBASE, Medline and Cochrane Library databases for the studies published between the establishment of the database to May 2021. The following search terms were used: "heart arrest", "cardiopulmonary resuscitation", "cardiac arrest" and "video-assisted", "telephone-assisted", "dispatcher-assisted", etc. Take PubMed as a working example, Box 1 lists the specific search strategy. In addition, we manually checked the reference list of every article for further suitable studies.

## Data extraction

Two researchers independently screened the articles, extracted data and cross-checked them. If there is a disagreement, it will be resolved through discussion or negotiation with a third party. After excluding the obviously irrelevant documents, the abstract and full text of each article were thoroughly read to determine its eligibility. If necessary, the original research authors were contacted via email or telephone to obtain the missing information. The following data were extracted: (1) Basic information of the included studies, including research title, first author, published journal, etc. (2) Baseline characteristics and intervention measures of the research object. (3) Key elements of the risk of bias evaluation. (4) Outcome measures and performance indicators.

## Risk of bias assessment

Two investigators independently evaluated the risk of bias for the included studies and cross-checked the results. The Cochrane handbook version 5.1.0 was used for assessing the risk of bias.

## Statistical analysis

Meta-analysis was conducted with Stata version 13.0 software. The count data were analyzed by calculating the odds ratio (OR) and its 95% confidence interval (CI). The measurement data involved different research types and measurement methods; thus, standardized mean difference (SMD) was used as the effect indicator, and each effect size was given a point. The heterogeneity among the included studies was analyzed by the  $\chi^2$  test ( $\alpha = 0.1$ ), and the  $I^2$  statistic was used to quantitatively judge the size of the heterogeneity. If there was no statistical heterogeneity, the fixed-effects model was used for interpreting the meta-analysis results; otherwise, the random-effects model was chosen and the source of the heterogeneity was further analyzed. Meanwhile, obvious clinical heterogeneity was analyzed descriptively.

## Results

### Study selection and risk of bias

A total of 259 relevant articles were retrieved by searching the online databases. Six studies(25–30), involving 537 volunteers, were included after layer-by-layer screening. The flow diagram of the study selection is illustrated in Fig. 1. The basic characteristics of the included studies are demonstrated in Table 1. The results of the risk of bias assessment are shown in Fig. 2.

Table 1  
The characteristics of included studies

Included studies	Loction	Study period	Subjects	Number of Subjects		Scenarios duration	Experiment procedure		Assessment
				V-CPR	T-CPR		V-CPR	T-CPR	
Lee,2021 <sup>[25]</sup>	Korea	October 2019 to July 2020.	Volunteers aged 18 years or older	88	43	6 min	Video call transition was performed after initiation of by stander chest compression	The dispatcher uses a standard audio instructed protocol to help the participant initiate and perform chest compression-only CPR.	(1) The mean proportion of adequate hand positioning during chest compressions. (2) The mean compression depth (3) Mean compression rate (4) Total no-flow time
Yang,2009 <sup>[26]</sup>	Taiwan	-	Volunteers above 16 years of age who have not received any CPR training within the last 5 years	43	53	4 min	Received interactive voice and video demonstration and feedback via a video cell phone.	Received only voice CPR instruction	(1) Chest compressions rate (2) Chest compressions depth (3) Proportion of subjects with sufficient rate (4) Proportion of chest compressions with appropriate depth (5) Proportion of correct hand positioning (6) Hands-off time (7) Time to first chest compression (8) Total duration of CPR instructions
Ecker,2020 <sup>[27]</sup>	Cologne	July to August 2018	Adult volunteers, lay people without any previous CPR training	50	50	8 min	The study assistant operated the camera function of the phone,volunteers activated EmergencyEye and started standardised video guided CPR.	The study assistant enabled the phone's speaker function, the EMS dispatcher then initiated standardised telephone guided CPR.	(1) Compression frequency 100 to 120 min-1 (2) Compression depth 5 to 6 cm (3) Correct hand position on the lower third of the sternum.

Included studies	Loction	Study period	Subjects	Number of Subjects		Scenarios duration	Experiment procedure		Assessment
				V-CPR	T-CPR		V-CPR	T-CPR	
Lee,2011 <sup>[28]</sup>	Korea	May 2010 to June 2010	Adult volunteers, lay people without any previous CPR training.	39	39	5 min	Instructed to make a voice call to a number, guided on how to play a video stored on the phone, and were further asked to do as shown on the video until the emergency medical technicians arrived.	Instructed to make a phone call to the same number,where they were guided by a dispatcher using the standardised protocol to perform compression-only CPR.	<p>(1) The mean compression rate</p> <p>(2) The number of subjects who performed an adequate compression rate ,</p> <p>(3) The mean compression depth,</p> <p>(4) The number of subjects who performed an adequate compression depth,</p> <p>(5) Adequate positioning of hands</p> <p>(6) Time to initiate continuous compressions</p> <p>(7) Hands-off time</p> <p>(8) The number of subjects who had no "hands-off" event after starting compressions</p>

Included studies	Loction	Study period	Subjects	Number of Subjects		Scenarios duration	Experiment procedure		Assessment
				V-CPR	T-CPR		V-CPR	T-CPR	
Stipulante,2016 <sup>[29]</sup>	Belgium	March 2013	High school Students volunteers, 16–25	60	60	8 min	Developed an original protocol of videoconference CPR instructions on the basis of the ALERT algorithm, followed the dispatcher's instructions and performed CPR.	Guided according to the ALERT protocol, given the instruction to 'put the speaker on' and to 'put the phone down' to receive further instruction.	<ul style="list-style-type: none"> <li>(1) Rate of chest compressions</li> <li>(2) Total number of chest compressions</li> <li>(3) Depth of chest compressions</li> <li>(4) Proportion of chest compressions with appropriate rate</li> <li>(5) Proportion of chest compression with appropriate depth</li> <li>(6) Proportion of chest compressions with correct hand positioning</li> <li>(7) Time for responsiveness check</li> <li>(8) Time for airway opening</li> <li>(9) Time for breathing check</li> <li>(10) Time to first compression</li> <li>(11) Hands-off time</li> </ul>

Included studies	Loction	Study period	Subjects	Number of Subjects		Scenarios duration	Experiment procedure		Assessment
				V-CPR	T-CPR		V-CPR	T-CPR	
BOLLE,2009 <sup>[30]</sup>	Norway	December 2006 and January 2007	High-school students	29	26	10 min	Dispatchers used a lap_x0002_top with a UMTS (3G) card, video camera, videovcommunication software and a standard headset.	Dispatchers used a telephone with a standard headset.	(1) Total number of compressions (2) Average depth (mm) (3) Average rate (n/min) (4) Average number per minute (5) Proportion done without error (6) Proportion done to correct depth (7) Proportion with correct hand position (8) Proportion done with full release (9) Time to first compression (s) (10) Total hands-off-chest time (s)

### The quality of chest compressions

The mean chest compression rate was reported in all six studies involving 537 volunteers(25–30). The results of the fixed-effects inverse-variance model indicated that video-guided CPR was significantly associated with the improved mean chest compression rate [OR = 0.66, 95% CI: 0.49–0.82, P < 0.001] (Fig. 3A). The weighted mean chest compression rate increased from 92.01 min<sup>-1</sup> in T-CPR group to 105.62 min<sup>-1</sup> in V- CPR group.

The mean chest compression depth was reported in all six studies(25–30) involving 537 volunteers. The results of random-effects REML model showed that the difference in the mean chest compression depth between the two groups was not statistically significant [OR = 0.18, 95% CI: -0.07–0.42, P = 0.15] (Fig. 3B). The proportion of chest compressions with correct hand positioning was reported in all six studies, however, four studies set this indicator as a continuous variable and the other two studies set as the dichotomous variables(28, 29). The first four studies included 382 volunteers, the results of random-effects REML model indicated that no significant difference was found between the T-CPR and V-CPR groups [OR = 0.24, 95% CI: -0.33–0.82, P = 0.41] (Fig. 3C 1). The last two studies included 155 volunteers, the results of random-effects REML model indicated that V-CPR was significantly associated with the improved proportion of chest compressions with correct hand positioning [OR = 1.63, 95% CI: 0.71–2.55, P < 0.001] (Fig. 3C 2)

There was obvious statistical heterogeneity in the number of subjects who performed adequate chest compressions and the proportion of chest compressions with appropriate depth. Thus, a qualitative description was provided. Three out of the four studies(26, 28, 29)demonstrated that the number of subjects who performed adequate chest compressions was significantly higher in V-CPR group than in T-CPR group. One out of the five studies(26) indicated that the proportion of chest compressions with appropriate depth in V-CPR was significantly greater than that in T-CPR group.

### Time-related quality parameters

Time to first chest compression was reported in five studies(25, 26, 28–30)involving 480 volunteers. The results of random-effects REML model showed that V-CPR was not associated with the time to first chest compression compared to T-CPR [OR = -0.12, 95% CI: -0.88–0.63, P = 0.75] (Fig. 4).

“Hands-off” time was reported in four studies(26, 28–30). However, the statistical heterogeneity was apparent; thus, the qualitative description was used. Two studies(28, 30) indicated that volunteers guided by telephone interrupted their chest compressions more frequently; and two other studies(26, 29) showed a longer hands-off time in V-CPR group due to the poor quality of the signal, and chest compressions were delayed or broken off.

## Discussion

In addition to the factors of the instructor and the guide, the modes of communication, including telephone voice guidance and remote video online guidance, are important factors affecting the quality of DA-CPR. There is no unified quality evaluation standard for DA-CPR at home and abroad, but in the comprehensive literature(31, 32), the overall quality evaluation index recommends the time of dispatcher accepts emergency calls to judge suspected OHCA, time of starting guidance CPR, time of starting chest compressions, location of chest compressions, frequency and depth, etc. The AHA 2015 guidelines recommended high-quality CPR required adequate chest compression depth (50–60 mm), adequate chest compression rate (100–120/min), full chest wall recoil, minimal pauses in chest compressions, correct hand position during compressions, and avoidance of hyperventilation(10).

Our systematic review included 6 randomized controlled trials reporting on the quality of DA-CPR under different communication methods. The meta-analysis results showed that video communication could improve the average chest compression rate of bystanders during simulated CAs. The compression speed increased from an average of  $92 \text{ min}^{-1}$  in the telephone group to more than  $100 \text{ min}^{-1}$ , reaching the standard compression rate for CPR. Abella et al. (22) found that a high chest compression rate is significantly related to the initial return of spontaneous circulation. It is expected that the compression speed improved by video communication can be transformed into a better chance of survival in reality. If the chest compressions are guided by moving video, it will be easier to maintain a proper chest compression rate. However, we also found, judging from the number of subjects who performed an adequate compression rate, there is still 10 ~ 70% proportion of subjects who did not achieve adequate compression rate. This reminds us that when guiding bystanders to perform cardiopulmonary resuscitation, we must emphasize that the compression frequency of bystanders reaches 100–120 times/min recommended by the AHA guidelines.

The depth of chest compressions is another key factor in high-quality CPR. Our meta-analysis revealed that video communication did not improve the average chest compression depth of bystanders during simulated CAs. At the same time, most of the compression depths did not meet the 2015 AHA guidelines for high-quality CPR with a depth of at least 5–6 cm in adults. Regardless of T-CPR or V-CPR, it is realized through interactive real-time feedback between dispatchers and subjects. In this study, most CPR performances did not meet the recommended compression depth. Therefore, it is necessary to emphasize the depth of chest compressions during interactive counseling, either through video presentations or phone calls.

Regarding the correct hand position during chest compressions, different description methods resulted in different results. When as a continuous variable, four studies indicated there was no significant difference between the V-CPR and T-CPR groups, but as the dichotomous variables, the other two studies showed V-CPR was significantly associated with the improved proportion of chest compressions with correct hand positioning. In included some studies, the correct hand position of the participants in T-CPR group was only 43.6%, and that of the participants in V-CPR group was only 45%. The possible reason is that the subjects in T-CPR group may call the dispatcher to ask questions, thus the position of their hands is changed during chest compressions. Video-guided CPR should be able to guide the correct hand position more intuitively in order to improve the correct hand position rate. However, some volunteers did not correct their hand position according to the instructions provided in the CPR video, which might be attributed to the small screen or location of the mobile phone. Different positions of the video phone may help to monitor and feedback the quality of CPR performed, such as the horizontal positioning, thereby achieving the adequate compression depth; on the other hand, the bird's eye view can optimize the judgment of hand positioning. Nevertheless, further research is needed to determine the best location of the video phone and the information obtained during DA-CPR.

Time to first chest compression is one of time-related quality parameters. In this meta-analysis, the V-CPR group had no significant improvement in time to first chest compression compared to the T-CPR group. In fact, only one study showed that the time to first chest compression was 72 s; while the remaining 5 studies were all greater than 100 s, and the longest reached 211 s. Such delay could have an impact on the survival rate of patients with CA. These were limited by the low quality of the video connection and poor training of the dispatcher in using video calls. Although the dispatcher gave accurate instructions, the bystanders in T-CPR group lacked a clear understanding and repeatedly asked questions, thus resulting in a time extension.

There were some inevitable limitations to this systematic review and meta-analysis. Firstly, this study incorporated simulation trials with mannequins, while might not represent real-life CAs. In fact, some bystanders can get plagued with fear; thus, more real-life studies with standardized protocols are needed in the future. Secondly, although the 2015 AHA guidelines recommended that dispatchers should provide CPR instructions with only chest compressions for adults with suspected OHCA, the emergency medical services are different and there are no unified standardized scheduling tools, hence, the instructions provided by the dispatcher may be varied. Thirdly, the research subjects included both adult volunteers and high school students, which could lead to differences in CPR quality due to their ability to learn from mobile videos. Although the adult volunteers (average age = 50 years) reported that they had no difficulty watching and understanding mobile videos, further research should be targeted on older volunteers who are more likely to encounter patients with CA. Fourthly, most included studies did not report the adjusted ORs of primary outcomes, and the ORs calculated by cross-tabs did not consider the confounding factors. Therefore, the results of this meta-analysis should be interpreted with caution.

## Conclusion

This study reveals that the average rate of chest compressions during simulated CAs can be improved by video-guided bystander CPR. However, the mean chest compression depth and time-related quality parameters, such as the first chest compression and "hand-off" time, demonstrate no significant improvement in V-CPR group. Video real-time guidance by dispatcher can improve the quality of the bystander CPR to a certain extent, but the quality is still not ideal, and there is a lack of guidance caused by poor video signal or inadequate interaction.

## Declarations

### Ethics approval and consent to participate

Not applicable

### Consent for publication

Not applicable

### Availability of data and material

Please contact author for data requests

### Competing interests

All authors declare no conflicts of interests.

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### Authors' contributions

This study was designed by Dr Dongfeng Pan and Peifeng Liang. All analysis of the data was performed by Peifeng Liang. Literature screening and data sorting were completed by Zhengjun Li and Xinzhong Ji. The first draft was written by Peifeng Liang. All coauthors participated intellectually and practically in the writing of the article.

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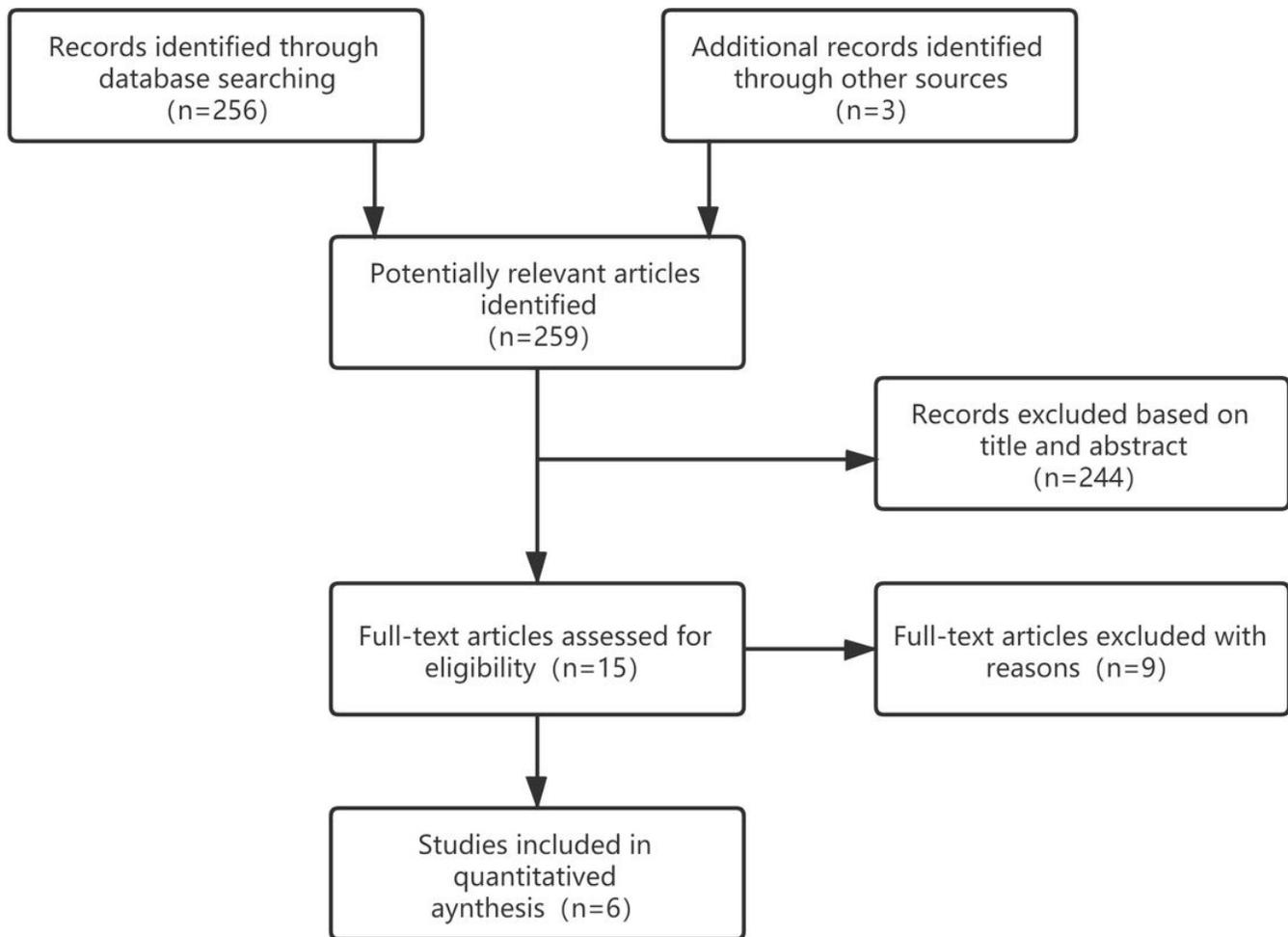
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## Box 1

Box 1 Lists the specific search strategy

#1 "cardiac arrest " [Mesh]  
#2 "cardiopulmonary resuscitation" [Mesh]  
#3 "cardiac arrest"  
#4 "heart arrest"  
#5 "cardiopulmonary resuscitation"  
#6 "CPR "  
#7 #1 OR #2 OR #3 OR #4 OR #5 OR #6  
  
#8 "dispatcher-assisted"  
#9 "dispatcher assistance "  
#10 #8 OR #9  
  
#11 "video-assisted"  
#12 "video-link"  
#13 "video-instructed"  
#14 #11 OR #12 OR #13  
  
#15 "audio-instructed"  
#16 "telephone-link"  
#17 "telephone-assisted"  
#18 #15 OR #16 OR #17

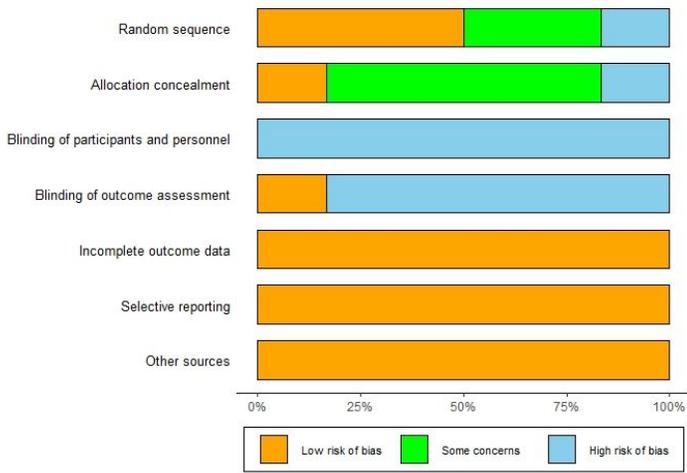
## Figures



**Figure 1**

The flow diagram of the study selection

Risk bias evaluation diagram included in System Evaluation



Risk of bias domains

Study	Risk of bias domains							Overall
	D1	D2	D3	D4	D5	D6	D7	
Lee 2011	+	X	X	X	+	+	+	+
Stuplancic 2016	+	+	X	X	+	+	+	+
Yang 2009	+	-	X	X	+	+	+	+
Ecker 2020	-	-	X	X	+	+	+	+
Bolle 2009	-	-	X	+	+	+	+	+
Lee 2021	X	-	X	X	+	+	+	+

D1: Random sequence  
 D2: Allocation concealment  
 D3: Blinding of participants and personnel  
 D4: Blinding of outcome assessment  
 D5: Incomplete outcome data  
 D6: Selective reporting  
 D7: Other sources

Judgement  
 + Low  
 - Unclear  
 X High

Figure 2

The results of the risk of bias assessmen

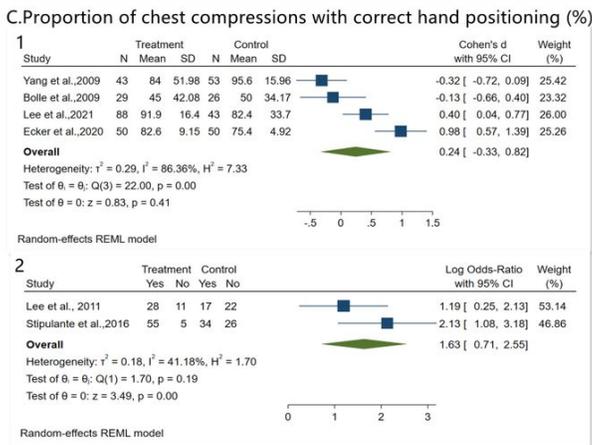
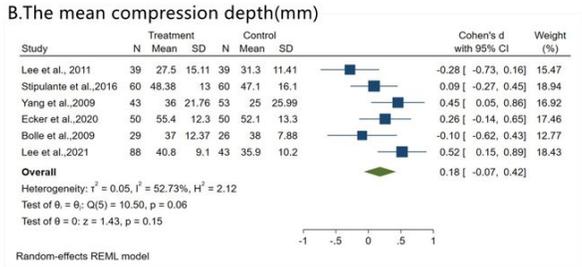
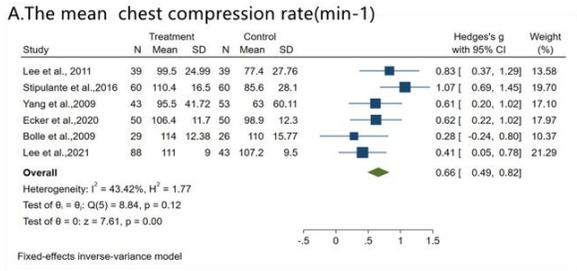


Figure 3

Forest plot of the quality outcomes of chest compressions

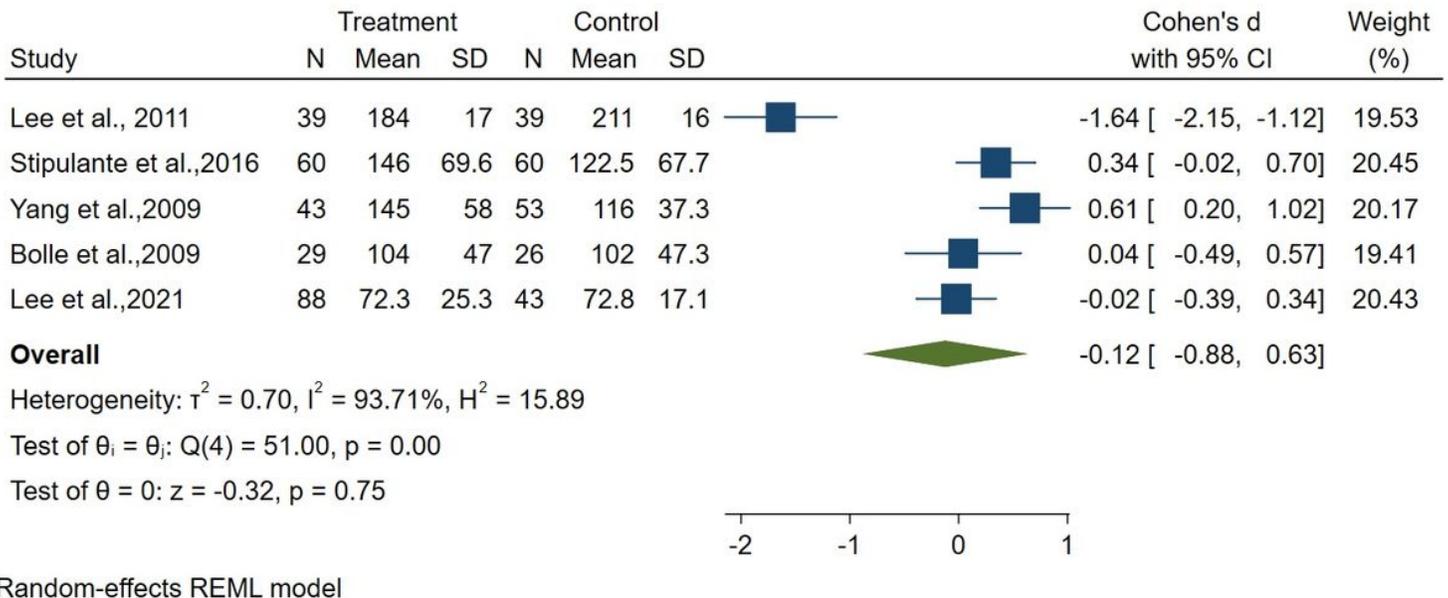


Figure 4

Forest plot of time to first chest compression