American Journal of Emergency Medicine 57 (2022) 60–69

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Outcome of cardiopulmonary resuscitation with different ventilation modes in adults: A meta-analysis

Yangyang Tang [a], Mengxue Sun [a], Aiqun Zhu [b,c,*]

[a] Xiangya Nursing School of Central South University, Changsha, Hunan, China
[b] Clinical Nursing Teaching and Research Section, The Second Xiangya Hospital of Central South University, Changsha, Hunan, China
[c] Department of Emergency Medicine, The Second Xiangya Hospital of Central South University, Changsha, Hunan, China

ARTICLE INFO

Article history:
Received 7 December 2021
Received in revised form 17 April 2022
Accepted 20 April 2022

Keywords:
Cardiopulmonary resuscitation
Ventilation modes
Outcome
Adult
Meta-analysis

ABSTRACT

Background: The optimal airway management strategy for cardiac arrest remains unclear. This study aimed to compare the effects of different initial airway interventions on improving clinical outcomes based on the 2010 cardiopulmonary resuscitation (CPR) guidelines and later.
Methods: We searched PubMed, EMBASE, and the Cochrane Library for CPR articles tailored to each database from October 19, 2010, to July 31, 2021, to compare endotracheal intubation (ETI), supraglottic airway (SGA), or bag-valve-mask ventilation (BMV). The initial results and long-term results were investigated by meta-analysis.
Results: Twenty-five articles (n = 196,486) were included. The ROSC rate in the ETI group (ES = 0.49, 95% CI: 0.38–0.59) was significantly higher than that in the SGA group (ES = 0.27, 95% CI: 0.20–0.34) and BMV group (ES = 0.24, 95% CI: 0.17–0.31). The rate of ROSC upon admission to the hospital in the ETI group (ES = 0.27, 95% CI: 0.13–0.42) was significantly higher than that in the SGA group (ES = 0.18, 95% CI: 0.13–0.23) and BMV group (ES = 0.16, 95% CI: 0.10–0.22). Compared with the BMV group (ES = 0.09, 95% CI: 0.04–0.14) and the SGA group (ES = 0.08, 95% CI: 0.05–0.10), the ETI group (ES = 0.14, 95% CI: 0.10–0.17) had a higher discharge rate, but all of the groups had the same neurological outcome (ETI group [ES = 0.06, 95% CI: 0.04–0.08], BMV group [ES = 0.05, 95% CI: 0.03–0.08] and SGA group [ES = 0.04, 95% CI: 0.03–0.05]).
Conclusions: Opening the airway is significantly associated with improved clinical outcomes, and the findings suggest that effective ETI based on mask ventilation should be implemented as early as possible once the patient has experienced cardiac arrest.

1. Introduction

Cardiopulmonary resuscitation (CPR) is the primary treatment for cardiac arrest. With the accumulation of relevant clinical evidence, the resuscitation guidelines have been continuously improved, and the success rate of resuscitation has been continuously improved, but the prognosis is still very poor. The American Heart Association (AHA) data showed that the adult survival rate of out-of-hospital cardiac arrest was 10.6%, while the adult survival rate of in-hospital cardiac arrest was 23.8% [1].

After cardiac arrest is recognized, the prompt initiation of CPR is perhaps the most important intervention to improve survival and neurological outcomes in a series of life recovery actions consisting of compression, airway, breathing, and defibrillation [2]. Airway intervention includes a series of progressive methods: compression-only, basic mouth-to-mouth ventilation, and advanced endotracheal intubation (ETI), which are selected according to the different situations, executors, and patient conditions [3].

The mode of ventilation management could depend on the setting or the etiology of the cardiac arrest. Previous meta-analyses of observational studies suggested that ETI had significantly better outcomes than supraglottic airway (SGA) in terms of ROSC, survival to hospital admission, and neurologically intact survival of out-of-hospital cardiac arrest patients [3,4]. Recently, the use of SGA has increased because SGA insertion is easier to learn than ETI and is less interrupted during chest compression. It seems to have advantages.

A network meta-analysis of randomized controlled trials suggested that SGA improved the rate of ROSC compared with ETI or BMV [5]. However, an animal experiment observed that with the extension of resuscitation time, SGA placement caused a greater reduction of carotid blood flow than endotracheal intubation [6]. An early large-scale clinical study also showed that the result of SGA was worse than that of ETI [7]. Some studies reported that bag-valve-mask ventilation (BMV) was independently associated with increased odds of good neurological

* Corresponding author at: Clinical Nursing Teaching and Research Section, The Second Xiangya Hospital of Central South University, Changsha, Hunan, China.
E-mail address: zhuaiqun74@csu.edu.cn (A. Zhu).

https://doi.org/10.1016/j.ajem.2022.04.027
0735-6757/

outcomes compared with SGA and ETI [8,9] and a higher rate of survival to discharge of cardiac etiology patients [10] and nontraumatic cardiac arrest patients [11].

Although confounding factors were fully considered in the pairwise comparison of these meta-analyses, there were potential deviations in the results, which may be because the samples were from different versions of CPR guidelines. Although international guidelines for cardiopulmonary resuscitation (CPR) have been revised every 5 years since 2000, there are few differences in the timing and mode of airway management and ventilation. However, compared with the previous CPR guidelines, one of the most important evidence-based recommendations of the 2010 CPR guidelines [12] for the performance of basic life support in adults was that following initial assessment, rescuers may begin CPR with chest compressions rather than opening the airway and delivering rescue breathing, and this sequence has continued to this day. To reduce the potential impact of this sequence on the results, we performed a meta-analysis based on CPR guidelines from 2010 and later, to compare the effects of different initial airway interventions in improving survival and neurological outcomes in patients with cardiac arrest.

2. Methods

2.1. Search strategy

We searched PubMed, EMBASE, and the Cochrane Library in accordance with different combinations of MeSH terms and keywords tailored to each database from October 19, 2010, to July 31, 2021. The search strings were as follows: PubMed, “cardiopulmonary resuscitation”[Mesh] and filters ‘Clinical Conference, Clinical Study, Comparative Study, Observational Study, Randomized Controlled Trial, Humans, English, Adult: 19 + years, from October 19, 2010 to July 31, 2021’; and EMBASE, cardiopulmonary AND (‘resuscitation’/exp. OR resuscitation) AND ([adult]/lim OR [aged]/lim) AND [humans]/lim AND [english]/lim AND [embase]/lim AND [2010−2021]/py AND (‘balloon’ OR ‘balloon pump’ OR ‘endotracheal tube’ OR ‘bag mask’ OR ‘laryngeal tube’ OR ‘manual emergency ventilator’ OR ‘mask’ OR ‘mechanical ventilator’ OR ‘occlusion balloon catheter’ OR ‘Airway device’ OR ‘Ventilator’ OR ‘video laryngoscope’). We also read the relevant review articles to avoid missing any relevant literature. Only studies within the specified time frame (October 19, 2010 to July 31, 2021) were considered for inclusion.

Two investigators independently scanned the titles and abstracts of all documents and then imported the possible relevant documents into EndNote X9 literature management software for further analysis. The two researchers independently screened the literature in strict accordance with the inclusion and exclusion criteria and finally cross-checked the two screening results. In cases of divergence, a third person was consulted for discussion and decision-making.

Eligible studies had to satisfy the following prespecified PICOS criteria: P (population), patients who underwent CPR based on the 2010 CPR guidelines or CPR execution time after October 19, 2010, and ≥ 18 years of age; I (intervention), ventilation modes (BMV, SGA, ETI); C (comparisons/comparators), None; O (outcomes), ROSC, ROSC at admission to hospital, survival to discharge, good neurological outcome; and S (study design), observational or clinical trials.

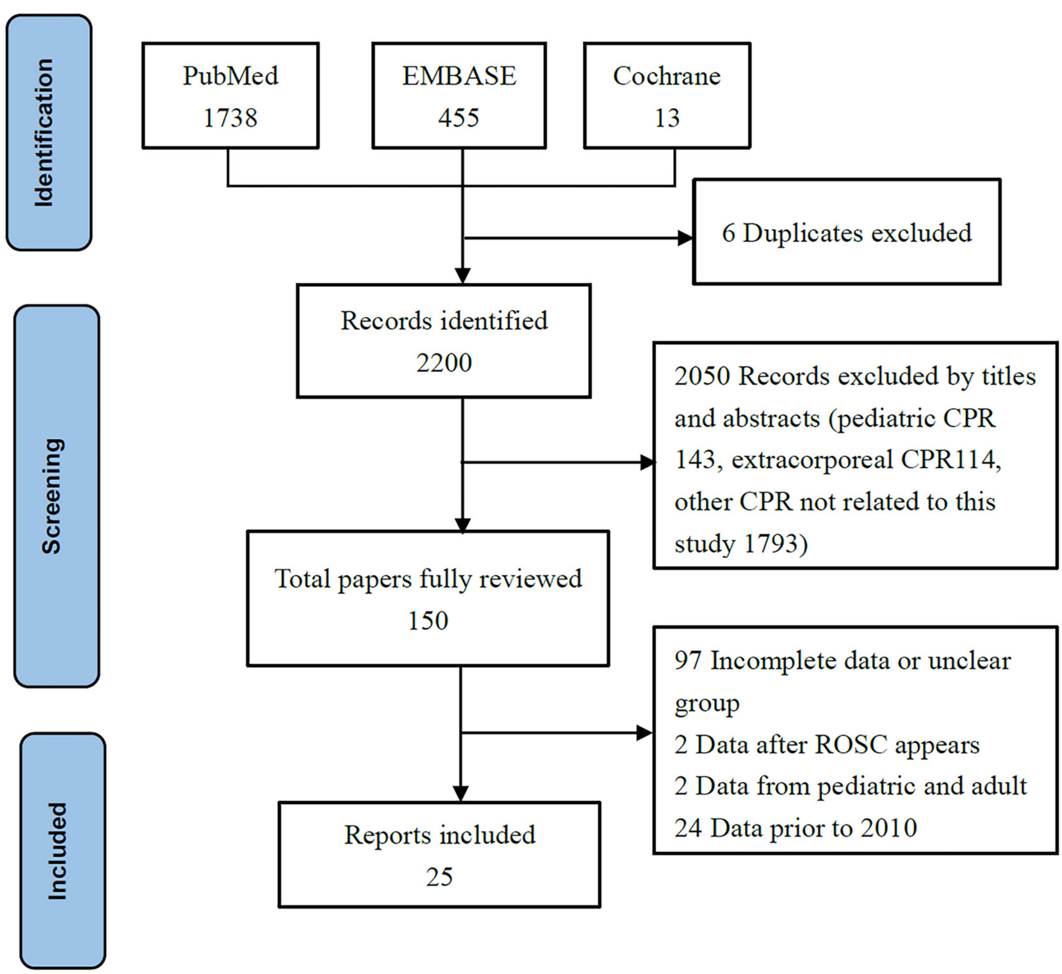

Fig. 1. Flow diagram of literature search and selection of included studies for meta-analysis.

Table 1
The Characteristics of included studies in this Meta-analysis

Study	Country	Data time	Age	CPR Area	CPR practitioner	Sample size	Outcomes (%)			
							ROSC	AHROSC	SD	GNO
Park, 2021	–	Dec. 2015 to Jun. 2019	≥15	OHCA	EMS	344	–	–	28.5	–
Yuksen, 2020	Thailand	Nov. 2016 to Oct. 2017	–	OHCA	EMS	1070	18.6	–	–	–
Lupton, 2020	–	–	≥ 18	OHCA	EMS, Bystander	2565	34.5	26.1	9.4	5.8
Poppe, 2019	–	July 2013 to Aug. 2015	>18	OHCA	EMS, Bystander	525	32.0	19.2	5.0	–
Skulec, 2019	–	Jun. 2018 to Mar. 2019	Adult	OHCA	EMS	18	66.7	44.4	–	33.3
Jinno, 2019	–	Jan. 2011 to Dec. 2015	≥18	OHCA	EMS	98,823	–	14.9	10.5	6.5
Bakran, 2019	–	2011 to 2017	Adult	OHCA	EMS	1247	–	18.0	–	–
Wang, 2019	–	Dec. 1, 2015 to Nov. 4, 2017	≥18	OHCA	EMS	3004	–	26.1	9.4	6.1
Sakurai, 2019	Japan	Jan. 2012 to Mar. 2013	≥18	OHCA	EMS	12,867	–	–	–	2.6
Chang, 2019	–	Apr. 2012 to Jul. 2015	≥18	OHCA	EMS	560	25.7	11.4	5.5	2.9
Benger, 2018	England	Jun. 2015 to Aug. 2017	≥18	OHCA	EMS	9296	–	6.8	–	6.6
Kurz, 2018	North American	Jun. 1, 2011, to Jun. 30, 2015	Adults	OHCA	EMS, Bystander	35,038	–	26.0	9.6	6.0
Jabre, 2018	France, Belgian	Mar. 9, 2015, to Jan. 2, 2017	≥18	OHCA	EMS, Bystander	2040	32.1	30.7	5.3	4.3
Nepal, 2018	–	Jul. 2012 to Jul. 2014	>14	IHCA	EMS	157	38.9	–	–	–
Bernhard, 2018	German	Jan. 1, 2010 to Jun. 30, 2016	–	OHCA	EMS	25,659	45.1	38.0	10.3	7.6
Lien, 2018	Taiwan	Jan. 2016 to Mar. 2017	Adult	OHCA	–	177	41.2	–	14.1	
Fiala, 2017	Austria	Sept. 2012 to Feb. 2014	–	OHCA	EMS	76	21.1	–	2.6	
Chalkias, 2017	Greece	–	>18	OHCA	EMS	300	86.0	–	–	–
Günaydın, 2016	Turkey	Apr. 2015 to Sept. 2015	≥18	OHCA	EMS	98	61.2	23.5	12.2	–
Movahedi, 2016	Iran	2010 guideline	18–85	IHCA	EMS	40	52.5	–	–	–
Benger, 2016	–	–	≥18	OHCA	EMS	615	–	30.9	9.2	–
Ono, 2015	Japan	Jun. 2012 to Jan. 2013.	–	OHCA	EMS	313	24.0	–	5.1	1.3
Maignan, 2015	France	Mar. 2011 to Feb. 2012	54–80	OHCA	EMS	82	–	13.4	2.4	–
Roth, 2015	Austria	Jun. 2011 to Dec. 2012	≥18	OHCA	EMS	469	14.7	12.6	3.4	3.0
Lee, 2015	Korea	Jan. 2011 to Dec. 2013	–	IHCA	EMS	229	72.5	–	32.3	–

CPR: cardiopulmonary resuscitation; ROSC: return of spontaneous circulation; AHROSC: admission to hospital ROSC; SD: survival to discharge; GNO: good neurological outcome.

We excluded (1) combined pediatric and adult CPR data and (2) the performance of CPR in special populations, including patients requiring external CPR or mechanical resuscitation or patients who had been intubated.

2.2. Data extraction

Standardized templates from the Cochrane Protocol were used to extract study characteristics into a Microsoft Excel spreadsheet (authors, publication year, geographic location, data collection date, age range, ventilation modes, primary outcome, secondary outcome). The two authors independently extracted information from each study and resolved any differences through discussion. The main result variables were ROSC and ROSC at admission to the hospital (including ROSC at ED arrival), and the secondary result variables were survival to discharge and good neurological outcome. Data from studies without specific data were excluded.

2.3. Quality assessments

According to the research types of the obtained articles, we used different tools to evaluate the risk of bias. For the clinical trials, we used the modified Jadad scale [13], which includes 8 items, ranging from 0 (the lowest quality) to 8 (the highest quality). Studies with scores of 6 or more were considered high quality. Case-control studies and cohort studies used the Newcastle–Ottawa Scale, which includes 8 items with a full score of 9, and a score of 7 or more was considered a high-quality study [14]. The two authors independently evaluated the quality of each study and resolved any disagreements through discussion.

2.4. Statistical analysis

All included studies were observational or clinical trials. We put the extracted clinical data into an Excel database for analysis using Stata 12.0. The data were divided into BMV, SGA, ETI and SGA + ETI groups. Data on BMV, SGA, and ETI ventilation were entered into the BMV, SGA, and ETI groups, respectively. Data using both SGA and ETI ventilation were entered into the SGA + ETI group. Outcomes were ROSC, ROSC at admission to the hospital, discharge survival, and good neurological function. Due to the heterogeneity of the studies, a random-effects model was used to evaluate the heterogeneity of the studies. Using the Cochrane Q test and the I^2 index, $P < 0.05$ was considered significant in the heterogeneity test. Publication bias was assessed by using Begg's and Egger's tests.

3. Results

3.1. Included studies, study characteristics, and quality assessment

The initial searches identified 2206 articles (Fig. 1). A total of 1738 articles were screened from PubMed, 455 from EMBASE and 13 from

Table 2
Result of the Newcastle-Ottawa scale quality assessment of the observational studies.

Studies	Newcastle-Ottawa Scale				
	Selection	Comparability	Outcome	Total score	Grade
Park 2021	4	1	2	7	high
Yuksen 2020	4	1	3	8	high
Lupton 2020	4	2	1	7	high
Poppe 2019	3	1	2	6	medium
Skulec 2019	4	1	3	8	high
Jinno 2019	4	2	3	9	high
Bakran 2019	2	1	2	5	medium
Wang 2019	4	2	3	9	high
Sakurai 2019	4	2	3	9	high
Chang 2019	4	1	2	7	high
Kurz 2018	4	2	3	9	high
Jabre 2018	4	2	3	9	high
Nepal 2018	4	2	1	7	high
Bernhard 2018	4	1	2	7	high
Lien 2018	4	1	3	8	high
Chalkias 2017	4	1	3	8	high
Fiala 2017	3	2	2	7	high
Günaydın 2016	2	2	2	6	medium
Movahedi 2016	4	1	2	7	high
Benger 2016	3	1	3	7	high
Ono 2015	4	2	2	8	high
Maignan2015	3	2	3	8	high
Roth 2015	2	2	3	7	high
Lee 2015	4	2	4	9	high

the Cochrane Library. After checking their titles and abstracts, 150 studies remained. Of these, 125 articles were excluded because the data were incomplete, the data included both children and adult patients, or the data included results prior to 2010, and 6 duplicated articles were removed. Although the American Heart Association defines cardiac arrest in children as involving individuals younger than 18 years of age, two articles with samples over the age of 14 were also included in our study because cardiopulmonary arrest is rare in children [15]. A total of 25 studies were finally included in the meta-analysis.

Table 1 displays the study characteristics and outcomes used in the meta-analysis. Of the 25 studies, 22 were from OHCA, and 21 had CPR performed only EMS. Two studies were from Japan [16,17]; 13 studies were from Thailand, England, North America, France and Belgium, Taiwan, Germany, Austria, Greece, Turkey, Iran, France, Austria, and Korea [18-30]; and the other 10 studies were from unknown geographical locations [31-40]. The number of patients in each study ranged from 40 to 98,823, with a total of 196,486 patients in all 25 studies (median, 7859 patients), of which 69,319 patients received BMV, 96,390 patients received SGA, 30,777 patients received ETI and 41,428 patients received SGA + ETI. Among all studies, the data collection time was after October 19, 2010, to ensure that CPR was performed in accordance with the 2010 CPR guidelines and later.

The 25 articles included one randomized controlled trial with a score of 6 (modified Jadad score) and 24 observational studies (see Table 2 for their quality evaluations). There were 3 articles graded medium and 22 articles graded high. Therefore, the overall quality of the literature base was good.

3.2. Return of spontaneous circulation

Sixteen [17,18,21-27,29,30,32-34,38,39] studies reported the results of the return of spontaneous circulation in different ventilation modes. Meta-analysis was performed on the effect size combinations, indicating significant heterogeneity among studies ($P < 0.0001$, $I^2 = 98.9\%$). Using the random effect model, the results showed that the ROSC rate in the ETI group (ES = 0.49, 95% CI: 0.38–0.59) was significantly higher than that in the BMV group (ES = 0.24, 95% CI: 0.17–0.31), SGA group (ES = 0.27, 95% CI: 0.20–0.34) and SGA + ETI group (ES = 0.46, 95%

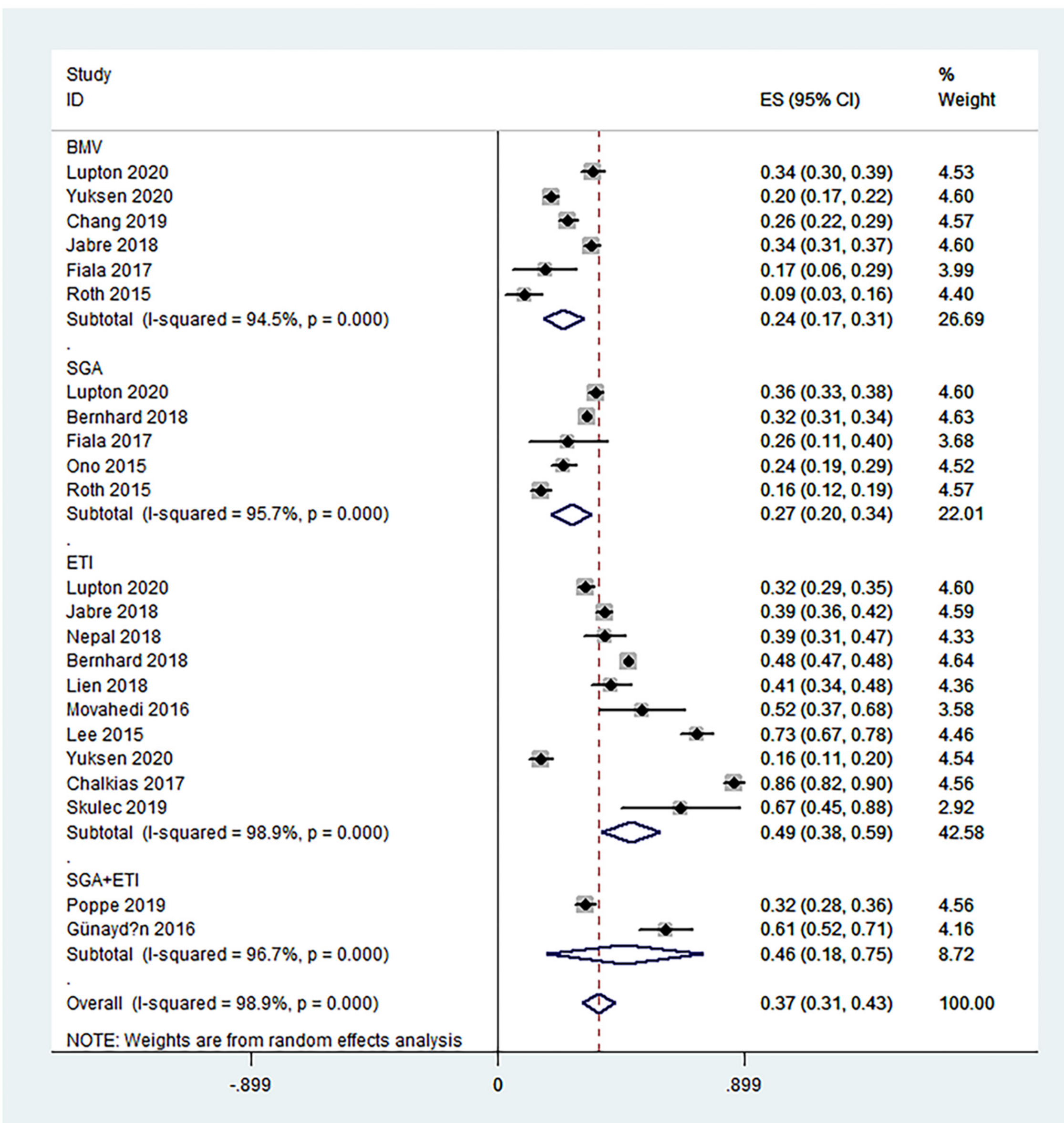

Fig. 2. Forest plot of the rate of return of spontaneous circulation.

CI: 0.18–0.75), whereas the overall pooled ROSC rate was ES = 0.37, 95% CI: 0.31–0.43, as shown in Fig. 2.

3.3. ROSC at admission to the hospital

Fourteen [19-22,28,29,32-38,40] studies reported the ROSC at admission to the hospital in different ventilation modes. Meta-analysis was performed on the effect size combinations, indicating significant heterogeneity among the studies ($P < 0.0001$, $I^2 = 99.7\%$). Using a random-effects model, the results showed that the ROSC at admission to the hospital in the ETI group (ES = 0.27, 95% CI: 0.13–0.42) was significantly higher than that in the BMV group (ES = 0.16, 95% CI: 0.10–0.22), SGA group (ES = 0.18, 95% CI: 0.13–0.23) and SGA + ETI group (ES = 0.25, 95% CI: 0.20–0.31), whereas the overall pooled ROSC at admission to the hospital was ES = 0.21, 95% CI: 0.17–0.25, as shown in Fig. 3.

3.4. Survival to discharge

Fourteen [20,22-24,26,28-33,37,38,40] studies reported the results of survival to discharge in different ventilation modes. Meta-analysis was performed on the effect size combinations, indicating significant heterogeneity among studies ($P < 0.0001$, $I^2 = 97.2\%$), and the results showed that the survival to discharge rate in the ETI group (ES = 0.14, 95% CI: 0.10–0.17) was significantly higher than that in the BMV group (ES = 0.09, 95% CI: 0.04–0.14), SGA group (ES = 0.08, 95% CI: 0.05–0.10) and SGA + ETI group (ES = 0.09, 95% CI: 0.06–0.12), whereas the overall pooled survival to discharge rate was ES = 0.099, 95% CI: 0.08–0.11, as shown in Fig. 4.

3.5. Good neurological outcome

The neurological status assessed via cerebral performance category (CPC) with a good neurological outcome defined as CPC I-II or modified

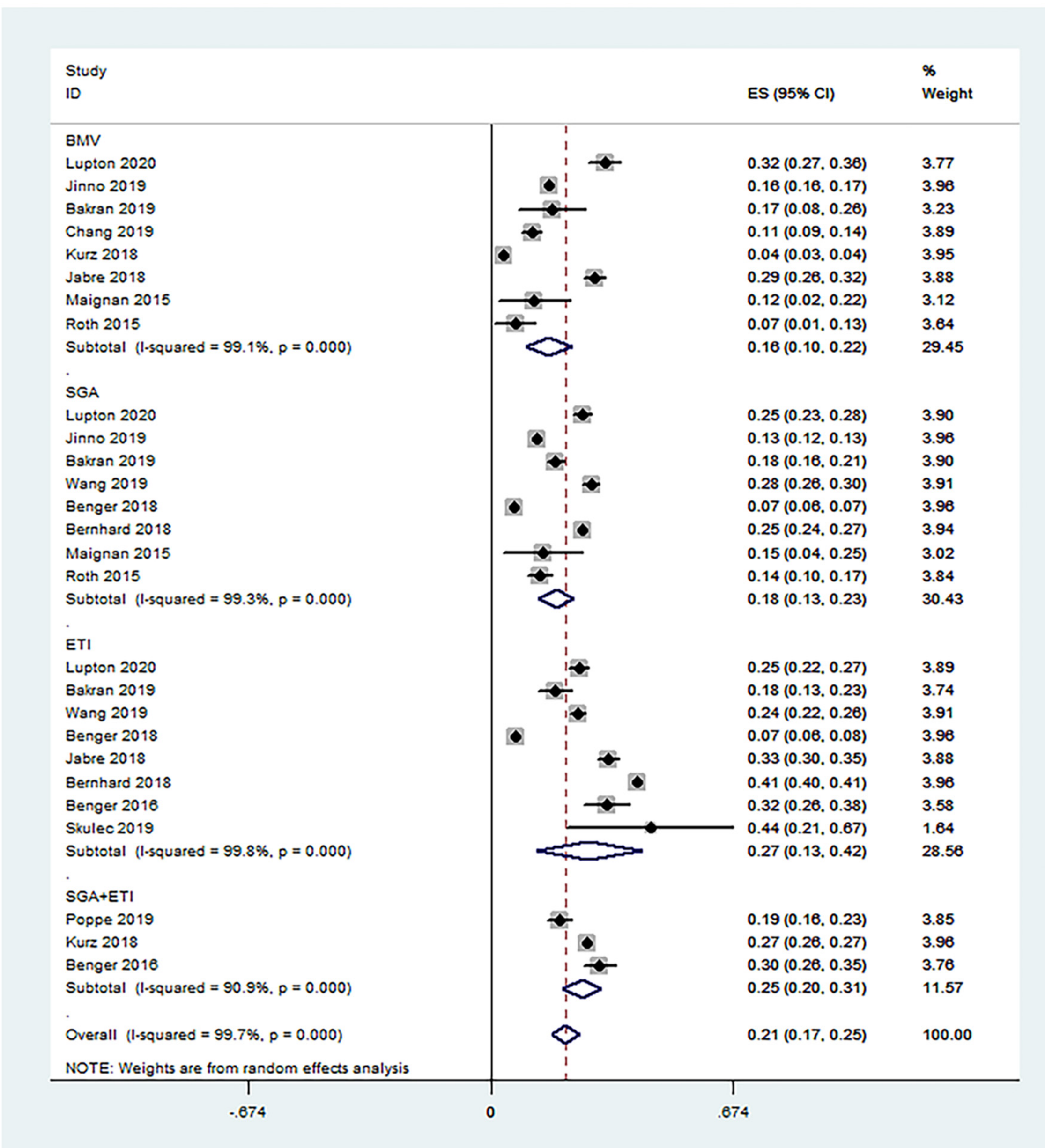

Fig. 3. Forest plot of the rate of return of spontaneous circulation at admission to hospital.

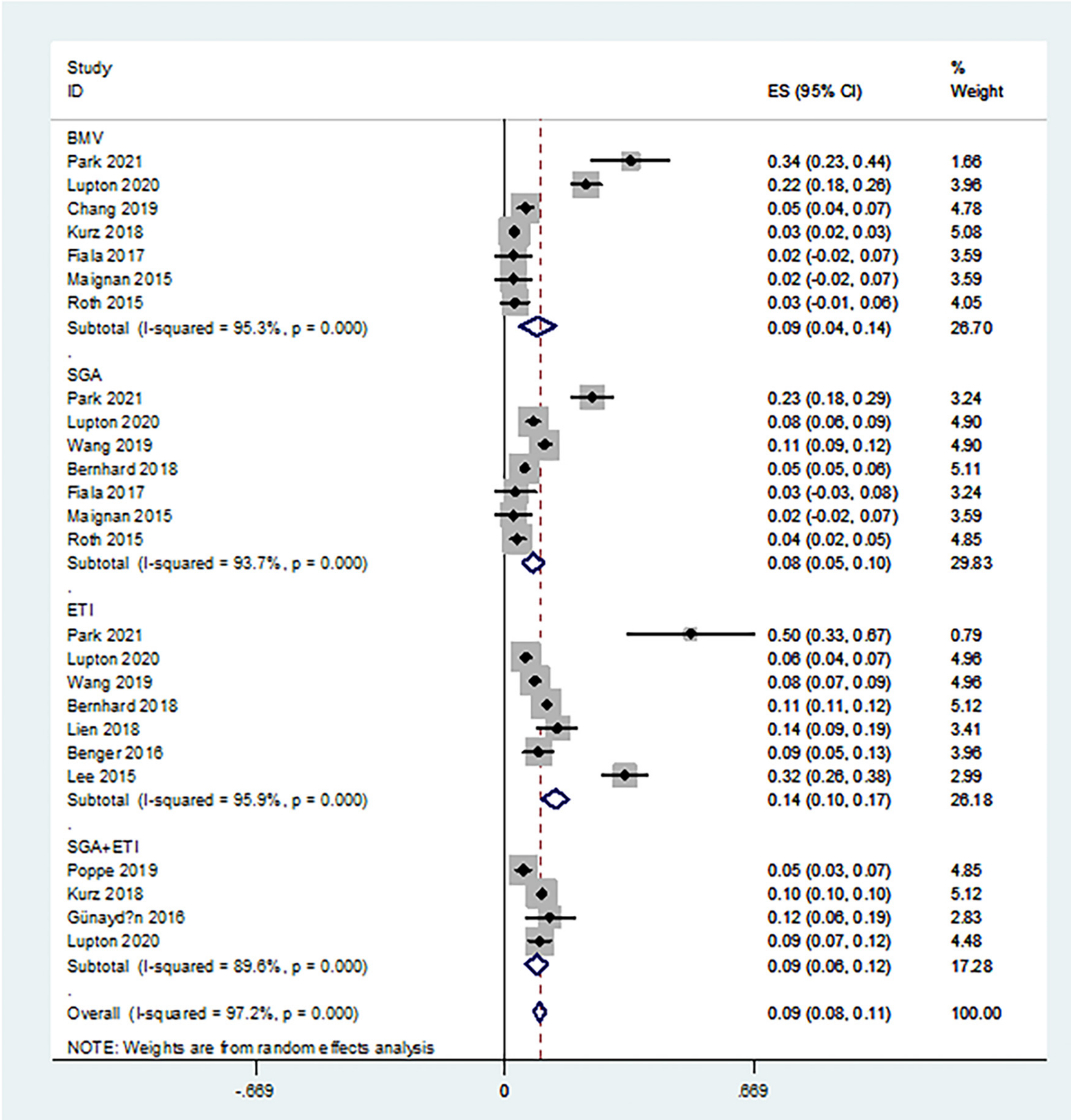

Fig. 4. Forest plot of the rate of survival to discharge.

Rankin score (MRS) with favorable neurological survival as ≤3. Twelve studies [16,17,19-22,29,32,34,35,37,38] reported neurological outcomes at discharge or one month, of which 7 were assessed by CPC. Meta-analysis was performed on the effect size combinations, indicating significant heterogeneity among studies. Using a random-effects model, the results showed that the good neurological outcome rate in the ETI group (ES = 0.06, 95% CI: 0.04–0.08) and SGA + ETI group (ES = 0.04, 95% CI: 0.01–0.08) was significantly higher than that in the BMV group (ES = 0.05, 95% CI:-0.03–0.08) and SGA group (ES = 0.04, 95% CI: 0.03–0.05), as shown in Fig. 5. The overall pooled good neurological outcome rate was ES = 0.0.05, 95% CI: 0.04–0.06.

3.6. Publication bias

Both Begg's test and Egger's test were conducted to assess the publication bias of the included literature. We observed potential publication bias with Begg's test (ROSC: $P < 0.001$; ROSC at admission to hospital: $P = 0.011$; survival to discharge: $P = 0.003$; good neurological outcome: $P = 0.398$) (Fig. 6: A, B, C, D) and Egger's test (ROSC: $P < 0.001$; ROSC at admission to hospital: $P < 0.001$; survival to discharge: $P = 0.278$; good neurological outcome: $P < 0.001$) (Fig. 6: E, F, G, H).

4. Discussion

This study reported the results from 25 published studies of more than 190,000 people who underwent CPR using different ventilation methods according to the 2010 CPR guidelines and later. The results showed that ETI had a better effect on CPR than SGA and BMV, SGA was better than BMV in terms of ROSC and admission ROSC, and the discharge rate and neurological recovery of the BMV group were better than those of SGA.

Previous CARES registry analysis by McMullan et al. demonstrated that ETI was associated with a higher sustained ROSC rate (OR 1.35, 95% CI 1.19–1.54), survival to hospital admission (OR 1.36, 95% CI 1.19–1.55), hospital survival (OR 1.41, 95% CI 1.14–1.76) and discharge with a good neurologic outcome (OR 1.44, 95% CI 1.10–1.88) when compared with cases managed via SGA [9]. Similarly, another analysis [7]

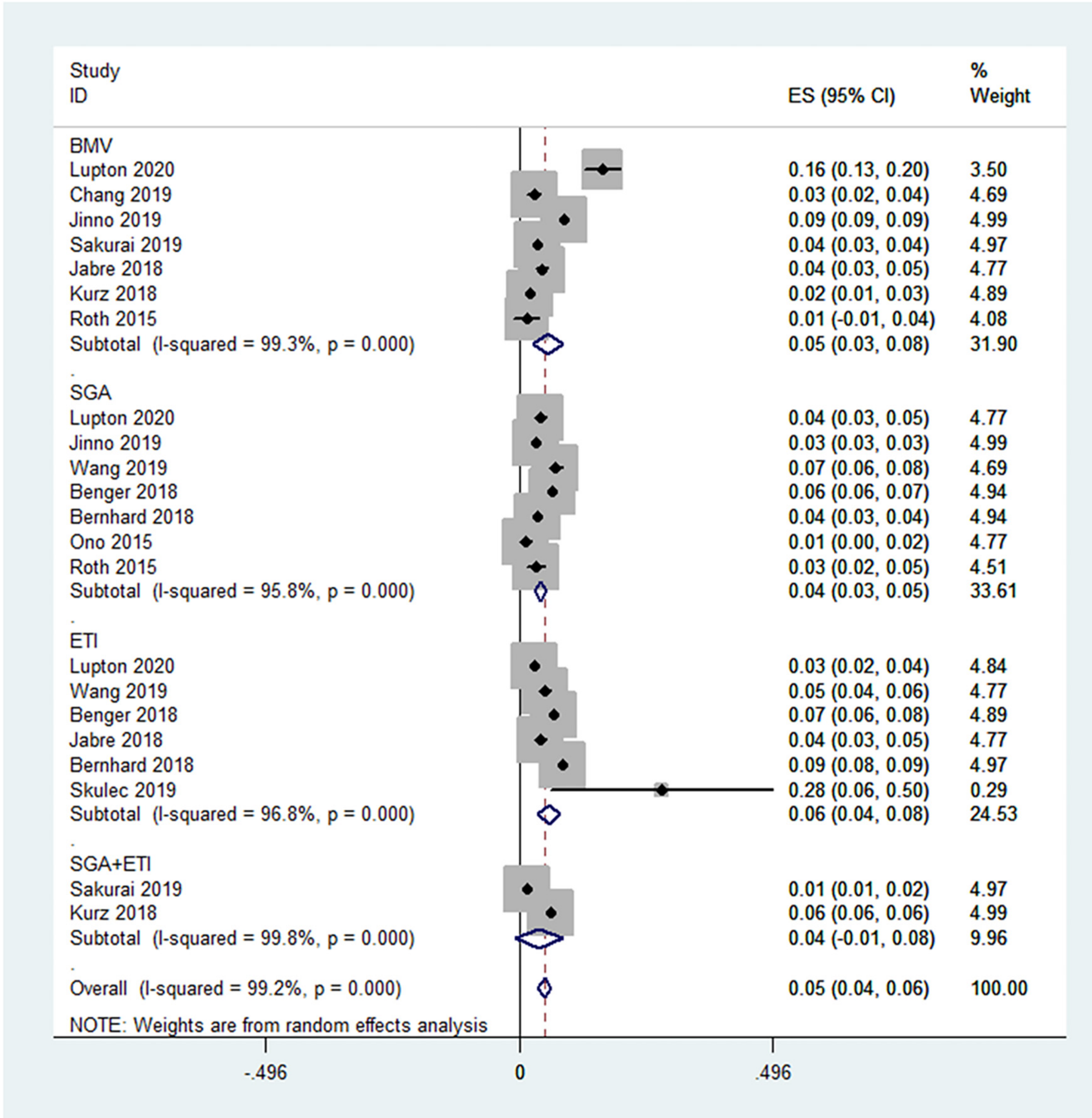

Fig. 5. Forest plot of the rate of good neurological outcome.

found that ETI was associated with increased survival to hospital discharge (adjusted OR 1.40, 95% CI 1.04–1.89), ROSC (adjusted OR 1.78, 95% CI 1.54–2.04) and 24 h survival (adjusted OR 1.74, 95% CI 1.49–2.04).

These previous findings are all consistent with the results of this meta-analysis. ETI had both good short-term and long-term effects on the treatment of patients with cardiac arrest. It is generally believed that after sudden cardiac arrest, there may be a sufficient oxygen reservoir to support the patient for approximately 4 min, and we do not recommend the routine use of passive ventilation techniques during conventional CPR for adults, such as continuous delivery of oxygen or air directly into the trachea [41]. Conversely, noncardiac sudden deaths, such as sudden asphyxial death (respiratory problems), hypoxemia and low blood flow before cardiac arrest, and reperfusion injury after ROSC, may lead to an insufficient oxygen pool that cannot meet the needs of the body [2]. The longer the cardiac arrest, the more the oxygen stored in the tissue is exhausted, and the body's demand for oxygen increases. In an animal experiment, higher minute ventilation resulted in better outcomes of pig cardiac arrest with 8 min of untreated VF through a thoracic pump [42]. On the premise of priority compression, early effective ventilation may be a means to reduce or delay irreversible damage. Therefore, the priority of ETI as the ventilation mode of CPR may be more beneficial to patients with cardiac arrest because we do not know the cause of cardiac arrest in most cases or how long CPR lasts if conditions permit.

Comparing SGA with BMV, although the SGA group had better ROSC and admission ROSC results and the BMV group had better neurological recovery and discharge effects, this difference was very small. A recent network meta-analysis also reported similar results, and there was no significant difference in discharge and neurological outcomes between the two [5]. We believe that the possible reason is that some patients only received BMV, as the most basic and simplest method of ventilation, and quickly resumed their spontaneous circulation and spontaneous breathing without the need for advanced airway management; thus, these patients often had better short-term and long-term results.

We cannot ignore the higher incidence of ROSC after SGA compared with BMV in this meta-analysis. SGA devices have become an important tool for advanced airway management. Because its serious complications, such as pulmonary aspiration and loss of airway, are rare and

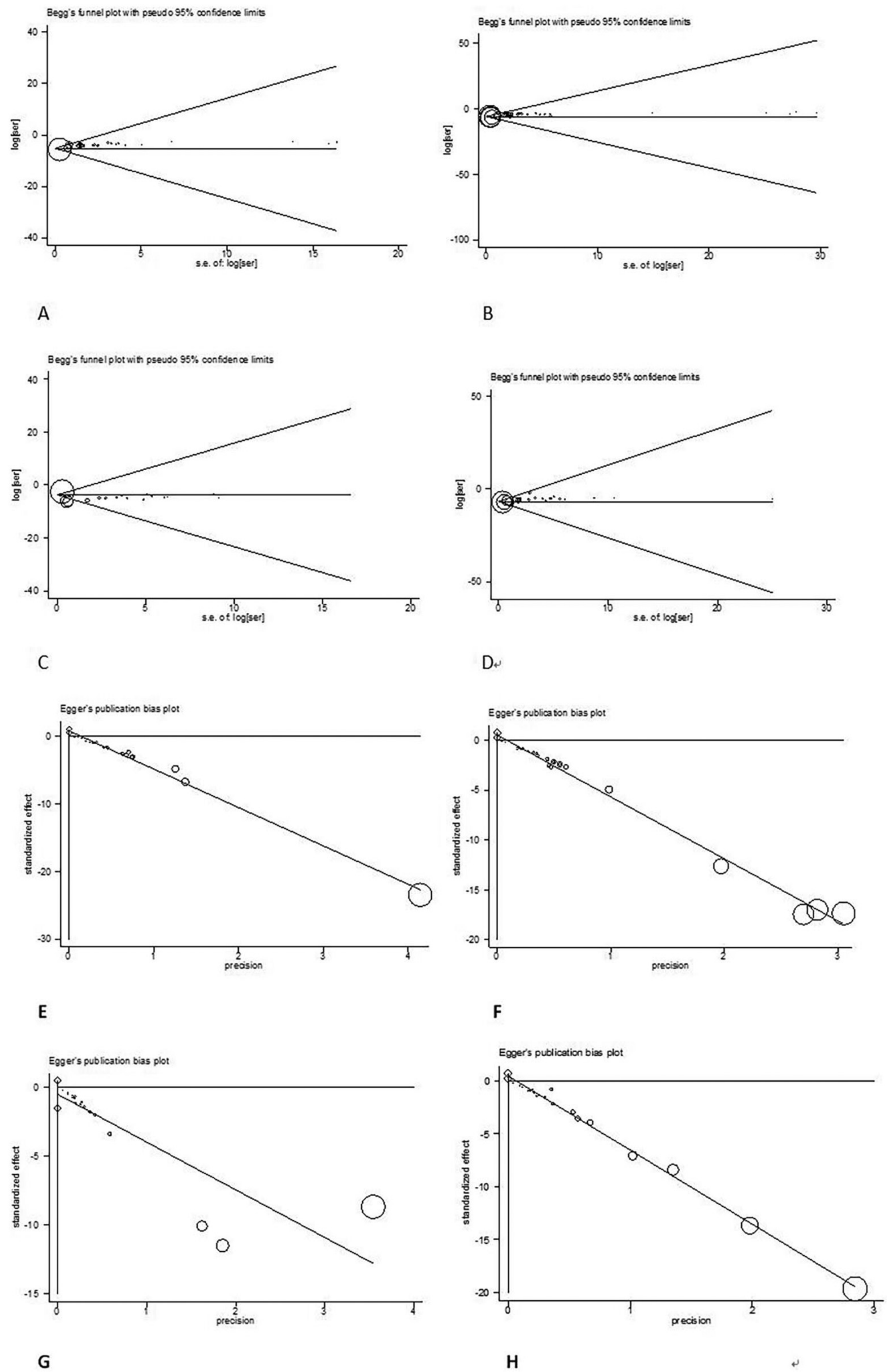

Fig. 6. Publiation bias was evaluated by Begg's test: (A) return of spontaneous circulation (ROSC); (B) admission to hospital ROSC; (C) survival to discharge; (D) good neurological outcome; and Egger's test; (E) ROSC; (F) admission to hospital ROSC; (G) survival to discharge; (H) good neurological outcome.

basically preventable, it is superior to BMV in ensuring effective airway patency [43].

Therefore, this evidence further supports the Recommendations—Updated 2019 [44]: either BMV or an advanced airway strategy may be considered during CPR for adult cardiac arrest in any setting (Class 2b; Level of Evidence B-R); if an advanced airway is used, SGA can be used for adults with OHCA in settings with a low tracheal intubation success rate or minimal training opportunities for ETI placement (Class 2a; Level of Evidence B-R). In other words, according to the five Levels of Evidence criteria [45], the priority for BMV is at third grade (Class 2b; Level of Evidence B-R), weak, evidence from 1 or more RCTs, and SGA is at second grade

(Class 2a; Level of Evidence B-R), moderate, and evidence from 1 or more RCTs [44].

We acknowledge that there is substantial heterogeneity in the included literature, which may come from different performers of CPR or the place where CPR occurred (in-hospital or out of hospital). It was observed from the literature data (Table 1) that the ROSC rate and discharge rate of CPR in hospital were significantly increased, which should be due to the rapid CPR response and early advanced airway management in cases of cardiac arrest. However, a randomized controlled trial [21] and a prospective observational study [46] both failed to demonstrate any benefits of advanced airway management in short-term and long-term cardiopulmonary resuscitation compared with basic airway management, while ETI and SGA, as advanced airway management, were supported as much as possible by this meta-analysis, which is consistent with the 2019 guidelines [44].

5. Study limitations

This meta-analysis included 25 studies involving 14 countries, but many study countries are unknown, so there is a certain bias in the analysis of the results, which may affect the generalizability of this study's results. There are many differences among witness-bystander CPR, transport and team CPR between OHCA and IHCA, so it is difficult to directly compare the resuscitation outcomes between OHCA and IHCA. Of the 25 studies in this meta-analysis, only three were from IHCA, and the total number of patients was 426. Therefore, we suggest further analyzing the differences between OHCA and IHCA in a large sample in the future. In addition, most of the included literature was in English, which may have led to the loss of relevant observational or retrospective data, so selection bias and recall bias were inevitable. Last, any type of cardiac arrest was taken into account, which may also be a confounding bias.

6. Conclusions

According to the 2010 CPR guidelines and later, endotracheal intubation has obvious advantages in improving short-term and long-term effects. In this review, supraglottic airway management was found to be slightly better than mask ventilation for ROSC, but the opposite was true for the discharge and neurological outcomes. Therefore, once the patient has undergone cardiac arrest, it is recommended to implement effective endotracheal intubation as early as possible based on mask ventilation.

CRediT authorship contribution statement

Yangyang Tang: Formal analysis, Data curation, Conceptualization, Writing – review & editing, Writing – original draft. **Mengxue Sun:** Formal analysis, Data curation, Writing – review & editing, Writing – original draft. **Aiqun Zhu:** Formal analysis, Data curation, Conceptualization, Writing – review & editing, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

This study was supported by grants from the project of Hunan Provincial Health Committee, China (grant number: 202214052730).

Ethics approval was obtained from the Ethics committee of Second Xiangya Hospital, China (2021/S383).

References

[1] Benjamin EJ, Blaha MJ, Chiuve SE, Cushman M, Das SR, Deo R, et al. Heart disease and stroke statistics-2017 update: a report from the American Heart Association. Circulation. 2017;10:e146–603. https://doi.org/10.1161/CIR.0000000000000485.

[2] Panchal AR, Bartos JA, Cabañas JG, Donnino MW, Drennan IR, Hirsch KG, et al. Part 3: adult basic and advanced life support: 2020 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2020;16:S366–468. https://doi.org/10.1161/CIR.0000000000000916.

[3] White L, Melhuish T, Holyoak R, Ryan T, Kempton H, Vlok R. Advanced airway management in out of hospital cardiac arrest: a systematic review and meta-analysis. Am J Emerg Med. 2018;12:2298–306. https://doi.org/10.1016/j.ajem.2018.09.045.

[4] Benoit JL, Gerecht RB, Steuerwald MT, McMullan JT. Endotracheal intubation versus supraglottic airway placement in out-of-hospital cardiac arrest: a meta-analysis. Resuscitation. 2015;93:20–6. https://doi.org/10.1016/j.resuscitation.2015.05.007.

[5] Wang CH, Lee AF, Chang WT, Huang CH, Tsai MS, Chou E, et al. Comparing effectiveness of initial airway interventions for out-of-hospital cardiac arrest: a systematic review and network Meta-analysis of clinical controlled trials. Ann Emerg Med. 2020;5:627–36. https://doi.org/10.1016/j.annemergmed.2019.12.003.

[6] Kim TH, Hong KJ, Shin SD, Lee JC, Choi DS, Chang I, et al. Effect of endotracheal intubation and supraglottic airway device placement during cardiopulmonary resuscitation on carotid blood flow over resuscitation time: an experimental porcine cardiac arrest study. Resuscitation. 2019;139:269–74. https://doi.org/10.1016/j.resuscitation.2019.04.020.

[7] Wang HE, Szydlo D, Stouffer JA, Lin S, Carlson JN, Vaillancourt C, et al. Endotracheal intubation versus supraglottic airway insertion in out-of-hospital cardiac arrest. Resuscitation. 2012;9:1061–6. https://doi.org/10.1016/j.resuscitation.2012.05.018.

[8] Hasegawa K, Hiraide A, Chang Y, Brown DF. Association of prehospital advanced airway management with neurologic outcome and survival in patients with out-of-hospital cardiac arrest. JAMA. 2013;3:257–66. https://doi.org/10.1001/jama.2012.187612.

[9] McMullan J, Gerecht R, Bonomo J, Robb R, McNally B, Donnelly J, et al. Airway management and out-of-hospital cardiac arrest outcome in the CARES registry. Resuscitation. 2014;5:617–22. https://doi.org/10.1016/j.resuscitation.2014.02.007.

[10] Shin SD, Ahn KO, Song KJ, Park CB, Lee EJ. Out-of-hospital airway management and cardiac arrest outcomes: a propensity score matched analysis. Resuscitation. 2012;3:313–9. https://doi.org/10.1016/j.resuscitation.2011.10.028.

[11] Hanif MA, Kaji AH, Niemann JT. Advanced airway management does not improve outcome of out-of-hospital cardiac arrest. Acad Emerg Med. 2010;9:926–31. https://doi.org/10.1111/j.1553-2712.2010.00829.x.

[12] Sayre MR, Koster RW, Botha M, et al. Part 5: adult basic life support: 2010 international consensus on cardiopulmonary resuscitation and emergency cardiovascular care science with treatment recommendations [published correction appears in circulation. 2013 Nov 5;128(19):e393]. Circulation. 2010;122(16 Suppl 2):S298–324.

[13] 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;1:1–12. https://doi.org/10.1016/0197-2456(95)00134-4.

[14] Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur J Epidemiol. 2010;9:603–5. https://doi.org/10.1007/s10654-010-9491-z.

[15] Vega RM, Kaur H, Edemekong PF. Cardiopulmonary arrest in children. StatPearls. Treasure Island (FL): StatPearls Publishing; 2021.

[16] Sakurai A, Kinoshita K, Maeda Y, Homma Y, Tahara Y, Yonemoto N, et al. Confirmed cardiac output on emergency medical services arrival as confounding by indication: an observational study of prehospital airway management in patients with out-of-hospital cardiac arrest. Emerg Med J. 2019;7:410–5. https://doi.org/10.1136/emermed-2018-208107.

[17] Ono Y, Hayakawa M, Maekawa K, Mizugaki A, Katabami K, Wada T, et al. Should laryngeal tubes or masks be used for out-of-hospital cardiac arrest patients? Am J Emerg Med. 2015;10:1360–3. https://doi.org/10.1016/j.ajem.2015.07.043.

[18] Yuksen C, Phattharapornjaroen P, Kreethep W, Suwanmano C, Jenpanitpong C, Nonnongku R, et al. Bag-valve mask versus endotracheal intubation in out-of-hospital cardiac arrest on return of spontaneous circulation: a National Database Study. Open Access Emerg Med. 2020;12:43–6. https://doi.org/10.2147/OAEM.S229356.

[19] Benger JR, Kirby K, Black S, Brett SJ, Clout M, Lazaroo MJ, et al. Effect of a strategy of a Supraglottic airway device vs tracheal intubation during out-of-hospital cardiac arrest on functional outcome: the AIRWAYS-2 randomized clinical trial. JAMA. 2018;8:779–91. https://doi.org/10.1001/jama.2018.11597.

[20] Kurz MC, Schmicker RH, Leroux B, Nichol G, Aufderheide TP, Cheskes S, et al. Advanced vs. basic life support in the treatment of out-of-hospital cardiopulmonary arrest in the resuscitation outcomes consortium. Resuscitation. 2018;128:132–7. https://doi.org/10.1016/j.resuscitation.2018.04.031.

[21] Jabre P, Penaloza A, Pinero D, Duchateau FX, Borron SW, Javaudin F, et al. Effect of bag-mask ventilation vs endotracheal intubation during cardiopulmonary resuscitation on neurological outcome after out-of-hospital cardiorespiratory arrest: a randomized clinical trial. JAMA. 2018;8:779–87. https://doi.org/10.1001/jama.2018.0156.

[22] Bernhard M, Behrens NH, Wnent J, Seewald S, Brenner S, Jantzen T, et al. "Out-of-hospital airway management during manual compression or automated chest compression devices: A registry-based analysis." "Prähospitales Atemwegsmanagement während der manuellen oder der mit automatischen Reanimationshilfen

durchgeführten kardiopulmonalen Reanimation: Eine Registeranalyse". Anaesthesist. 2018;2:109–17. https://doi.org/10.1007/s00101-017-0401-6.
[23] Lien WC, Hsu SH, Chong KM, Sim SS, Wu MC, Chang WT, et al. Data on evaluation of proficiency for the US-CAB curriculum. Data Brief. 2018;17:965–8. https://doi.org/10.1016/j.dib.2018.02.021.
[24] Fiala A, Lederer W, Neumayr A, Egger T, Neururer S, Toferer E, et al. EMT-led laryngeal tube vs. face-mask ventilation during cardiopulmonary resuscitation - a multicenter prospective randomized trial. Scand J Trauma Resusc Emerg Med. 2017; 25:104. https://doi.org/10.1186/s13049-017-0446-1.
[25] Chalkias A, Pavlopoulos F, Koutsovasilis A, d'Aloja E, Xanthos T. Airway pressure and outcome of out-of-hospital cardiac arrest: a prospective observational study. Resuscitation. 2017;110:101–6. https://doi.org/10.1016/j.resuscitation.2016.10.023.
[26] Günaydın YK, Çekmen B, Akıllı NB, Köylü R, Sert ET, Cander B. Comparative effectiveness of standard CPR vs active compression-decompression CPR with CardioPump for treatment of cardiac arrest. Am J Emerg Med. 2016;3:542–7. https://doi.org/10.1016/j.ajem.2015.12.066.
[27] Movahedi A, Mirhafez SR, Behnam-Voshani H, Reihani H, Kavosi A, Ferns GA, 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. 2016;4:448–54. https://doi.org/10.1111/acem.12903.
[28] Maignan M, Koch FX, Kraemer M, Lehodey B, Viglino D, Monnet MF, et al. Impact of laryngeal tube use on chest compression fraction during out-of-hospital cardiac arrest. A prospective alternate month study. Resuscitation. 2015;93:113–7. https://doi.org/10.1016/j.resuscitation.2015.06.002.
[29] Roth D, Hafner C, Aufmesser W, Hudabiunigg K, Wutti C, Herkner H, et al. Safety and feasibility of the laryngeal tube when used by EMTs during out-of-hospital cardiac arrest. Am J Emerg Med. 2015;8:1050–5. https://doi.org/10.1016/j.ajem.2015.04.048.
[30] Lee DH, Han M, An JY, Jung JY, Koh Y, Lim CM, et al. Video laryngoscopy versus direct laryngoscopy for tracheal intubation during in-hospital cardiopulmonary resuscitation. Resuscitation. 2015;89:195–9. https://doi.org/10.1016/j.resuscitation.2014.11.030.
[31] Park HA, Ahn KO, Lee EJ, Park JO. Association between survival and time of on-scene resuscitation in refractory out-of-hospital cardiac arrest: a cross-sectional retrospective study. Int J Environ Res Public Health. 2021;18:496. https://doi.org/10.3390/ijerph18020496.
[32] Lupton JR, Schmicker RH, Stephens S, Carlson JN, Callaway C, Herren H, et al. Outcomes with the use of bag-valve-mask ventilation during out-of-hospital cardiac arrest in the pragmatic airway resuscitation trial. Acad Emerg Med. 2020;5:366–74. https://doi.org/10.1111/acem.13927.
[33] Poppe M, Stratil P, Clodi C, Schriefl C, Nürnberger A, Magnet I, et al. Initial end-tidal carbon dioxide as a predictive factor for return of spontaneous circulation in nonshockable out-of-hospital cardiac arrest patients: a retrospective observational study. Eur J Anaesthesiol. 2019;7:524–30. https://doi.org/10.1097/EJA.0000000000000999.
[34] Skulec R, Vojtisek P, Cerny V. Correlation between end-tidal carbon dioxide and the degree of compression of heart cavities measured by transthoracic echocardiography during cardiopulmonary resuscitation for out-of-hospital cardiac arrest. Crit Care. 2019;23:334. https://doi.org/10.1186/s13054-019-2607-2.
[35] Jinno K, Hifumi T, Okazaki T, Kuroda Y, Tahara Y, Yonemoto N, et al. Association between prehospital Supraglottic airway compared with bag-mask ventilation and Glasgow-Pittsburgh cerebral performance category 1 in patients with out-of-hospital cardiac arrest. Circ J. 2019;12:2479–86. https://doi.org/10.1253/circj.CJ-19-0553.
[36] Bakran K, Šribar A, Šerić M, Antić-Šego G, Božić MA, Prijić A, et al. Cardiopulmonary resuscitation performed by trained providers and shorter time to emergency medical team arrival increased patients' survival rates in Istra County, Croatia: a retrospective study. Croat Med J. 2019;4:325–32. https://doi.org/10.3325/cmj.2019.60.325.
[37] Wang HE, Humbert A, Nichol G, Carlson JN, Daya MR, Radecki RP, et al. Bayesian analysis of the pragmatic airway resuscitation trial. Ann Emerg Med. 2019;6: 809–17. https://doi.org/10.1016/j.annemergmed.2019.05.009.
[38] Chang MP, Lu Y, Leroux B, Aramendi Ecenarro E, Owens P, Wang HE, et al. Association of ventilation with outcomes from out-of-hospital cardiac arrest. Resuscitation. 2019;141:174–81. https://doi.org/10.1016/j.resuscitation.2019.05.006.
[39] Shrestha BK, Sharma A, Gyawali PK. Differences in return of spontaneous circulation in early vs late endotracheal intubation among patients in hospital cardiac arrest. J Nepal Health Res Counc. 2018;15:286–9. https://doi.org/10.3126/jnhrc.v15i3.18857.
[40] Benger J, Coates D, Davies S, Greenwood R, Nolan J, Rhys M, et al. Randomised comparison of the effectiveness of the laryngeal mask airway supreme, i-gel and current practice in the initial airway management of out of hospital cardiac arrest: a feasibility study. Br J Anaesth. 2016;2:262–8. https://doi.org/10.1093/bja/aev477.
[41] Kleinman ME, Brennan EE, Goldberger ZD, et al. Part 5: adult basic life support and cardiopulmonary resuscitation quality: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2015;132(18 Suppl 2):S414–35.
[42] Tan D, Sun J, Geng P, Ling B, Xu J, Walline J, et al. Duration of cardiac arrest requires different ventilation volumes during cardiopulmonary resuscitation in a pig model. J Clin Monit Comput. 2020;3:525–33. https://doi.org/10.1007/s10877-019-00336-6.
[43] Gordon J, Cooper RM, Parotto M. Supraglottic airway devices: indications, contraindications and management. Minerva Anestesiol. 2018;3:389–97. https://doi.org/10.23736/S0375-9393.17.12112-7.
[44] Panchal AR, Berg KM, Hirsch KG, Kudenchuk PJ, Del Rios M, Cabañas JG, et al. 2019 American Heart Association focused update on advanced cardiovascular life support: use of advanced Airways, vasopressors, and extracorporeal cardiopulmonary resuscitation during cardiac arrest: An update to the American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2019;24:e881–94. https://doi.org/10.1161/CIR.0000000000000732.
[45] Halperin JL, Levine GN, Al-Khatib SM, et al. Further evolution of the ACC/AHA clinical practice guideline recommendation classification system: a report of the American College of Cardiology/American Heart Association task force on clinical practice guidelines. Circulation. 2016;133:1426–8.
[46] Hagihara A, Onozuka D, Nagata T, Hasegawa M. Effects of advanced life support on patients who suffered cardiac arrest outside of hospital and were defibrillated. Am J Emerg Med. 2018;1:73–8. https://doi.org/10.1016/j.ajem.2017.07.018.