Laryngeal mask versus endotracheal intubation for pre-hospital emergency airway management: a meta-analysis of randomized manikin and human studies

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Abstract

Background Pre-hospital emergency airway management plays an important role in pre-hospital care. Laryngeal masks are increasingly employed for the airway management of pre-hospital critical patients and have achieved promising results. Although several randomized controlled trials have reported benefits, the efficacy of laryngeal masks in pre-hospital emergency airway management compared to endotracheal intubation have not been systematically reviewed.

Methods Electronic databases (PubMed, Cochrane Library, Embase, Scopus and CNKI) were searched up to April 2019 for related randomized studies. Outcome indicators were overall intubation success rates, success rates of the initial intubation, insertion time, ventilation efficiency rates, SpO₂ rise time and blood gas index. Two investigators selected the trials, extracted the data according to inclusion and exclusion criteria, and assessed the quality of the literature according to the Jada score. The meta-analysis was performed using stata14.0 software.

Results We included 9 randomized manikin studies and 31 human studies. Meta-analysis of the manikin studies showed that the overall intubation success rates of the laryngeal mask group [RR=1.10, 95% CI (1.02, 1.18), P<0.05] and the success rates of first intubation [RR=1.25, 95% CI (1.01, 1.55), P <0.05] were significantly higher than the endotracheal intubation group. The insertion time of the laryngeal mask group was also significantly shorter [SMD = -1.53, 95% CI (-1.88, -1.17), P <0.05]. In human studies, excluding the success rates of first intubation and insertion time, the laryngeal mask was superior to endotracheal intubation and improved the patients' blood gas index and shortened the SpO₂ rise time. All the results were statistically significant.

Conclusions Compared to endotracheal intubation, laryngeal masks could quickly and effectively improve patient ventilation in pre-hospital emergencies, highlighting its utility for clinical application .

Introduction

Pre-hospital emergency airway management is crucial in pre-hospital care and is associated with the outcomes of critical patients. Effective airway management avoids systematic hypoxia and ensures organ oxygenation to reduce mortality rates and extend the time for further medical treatments of pre-hospital critical patients. Although tracheal intubation is regarded as an effective method to maintain pulmonary ventilation, it requires a skilled operator, precise placement and rapid responses (within 20 s), reducing its success rates. In particular, the success rates of tracheal intubation by non-clinical emergency personnel are generally low. In addition, tracheal intubation leads to laryngeal edema, airway injury, and other complications. Hence, clinicians do not support tracheal intubation due to concerns over its safety and effectiveness [1].

The laryngeal mask is a novel supraglottic ventilation device that was designed based on the anatomical structure of the human pharynx, which achieves good ventilation levels without intubation. The mask can effectively reduce iatrogenic infections and pharyngeal compression injury, limiting the disruption of pharyngeal hemodynamics [2-3]. Recent studies reported a high efficacy of ventilation therapy when the

laryngeal mask was applied to pre-hospital emergency patients. However, the majority of these studies had small sample sizes and did not adequately evaluate laryngeal mask efficacy. Hence, the effectiveness and safety of its application in pre-hospital emergency patients remains controversial [4-5]. In this study, we included randomized manikin and human studies to compare the ventilation effects of laryngeal masks and endotracheal intubation in pre-hospital emergencies, so as to provide reference for clinical practice.

Methods

This systematic review and meta-analysis were conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement to report [6].

Data Sources and Searches

Electronic databases (PubMed, Cochrane Library, Embase, Scopus and CNKI) were searched up to April 2019 for related randomized studies regarding laryngeal masks versus endotracheal intubation. References of the relevant studies were screened to incorporate studies that met the criteria. The retrieval strategy was adjusted according to different databases using the search terms: endotracheal intubation, laryngeal mask, and randomized controlled trial. The combination of mesh and free words were adopted and all retrieval strategies were determined by pre-retrieval. The search strategy of was as follows: (Randomized) or randomized controlled study [Title/Abstract]) OR "Randomized Controlled Trial" [Publication Type])) AND (Laryngeal Mask [Title/Abstract] OR Mask, Laryngeal [Title/Abstract] OR Masks, Laryngeal [Title/Abstract] OR Laryngeal Mask Airway [Title/Abstract] OR Airway, Laryngeal Mask [Title/Abstract] OR Airways, Laryngeal Mask [Title/Abstract] OR Laryngeal Mask Airway [Title/Abstract])) OR "Laryngeal Masks"[Mesh]) AND (Anesthesia, Endotracheal[Title/Abstract] OR Endotracheal Anesthesias[Title/Abstract] OR Intratracheal Anesthesia[Title/Abstract] OR Anesthesias, Intratracheal[Title/Abstract] OR Intratracheal Anesthesias[Title/Abstract] OR Anesthesia, Intratracheal[Title/Abstract] OR Endotracheal Anesthesia[Title/Abstract] OR endotracheal tube [Title/Abstract] OR tracheal tube [Title/Abstract]) OR "Anesthesia, Endotracheal"[Mesh]).

Study design

Randomization

Inclusion criteria

Pre-hospital emergency situations: the study group underwent any type of laryngeal mask airway management. The control group underwent endotracheal intubation.

Exclusion criteria

Non-pre-hospital emergency situations, including general anesthesia surgery and non-randomization were excluded.

Outcomes

The overall intubation success rates, the success rates of initial intubation, insertion times, ventilation efficiency rates, SpO₂ rise times and blood gas indexes were recorded.

Literature screening and data extraction

Two investigators read the titles and abstracts of the retrieved studies and excluded those that failed to meet the inclusion criteria. Full texts were those that met the inclusion criteria to determine study compliance. References were cross-checked in accordance with the inclusion criteria. Disagreements were resolved through discussions. According to the pre-designed form, the research contents mainly included: (1) general information: title of the article, author's name, source of the publications and time of the publications; (2) the characteristics of the research: the research object, study baseline comparability, and interventions; (3) the observation index: overall intubation success rates, the success rate of the initial intubation and insertion time.

Quality assessment

The Jada scale was used to evaluate randomized research methods, blind methods, a loss of follow-up and withdrawal. The score was 0 to 5, ≤ 2 points were classified as low-quality studies, and ≥ 3 points were classified as high-quality studies. An independent quality assessment of the included literature was performed by two individuals and conducted and checked. Studies with inconsistent evaluations were identified through discussions and confirmed by a third reviewer.

Data Analysis

Stata 14.0 statistical software was used for meta-analysis. Continuous variables were expressed as mean standard differences ($m \pm SD$ / SMD) due to non-uniform units. If an article provided only the median and interquartile range (IQR), SD values were calculated according to the Cochrane manual equation: $SD = IQR/1.35$ [7]. Dichotomous variables were expressed as a risk ratio (RR). The 95% feasible interval (CI) was calculated for both effect sizes. Heterogeneity analysis was performed using Chi-square (χ^2) tests. When $P < 0.05$ and $I^2 > 50\%$, heterogeneity existed between the studies. If no heterogeneity was observed, the fixed effect model was used. In other cases, the random effects model was employed. Subgroup analysis was conducted to explore the source of heterogeneity, such as environment and participant identity. Descriptive analysis was used if the sources of heterogeneity were not identified. Sensitivity analysis was performed through altering the effect model. Publication bias was assessed using funnel plots and Egger's tests to determine reliability. If bias existed, metatrim methods were performed.

Results

Study characteristics and quality assessment

According to the search strategy, a total of 996 related articles were retrieved. A total of 292 articles were excluded after duplicates were removed and 673 articles were initially included. After reading titles, abstracts and full texts, 667 articles were excluded, of which 35 were reviews. A total of 14 reports, 532 non-pre-hospital emergency studies, 40 that did not use laryngeal masks, 36 with non-randomized data and 7

with insufficient data were excluded. Finally, 9 randomized studies [8-16] on manikins and 31 randomized studies [17-47] on humans were included. In the manikin studies, the participants included medical students, paramedics, anesthesiologists, EMT, nurses, intensive care and emergency physicians. The human studies included cases of cardiac arrest, respiratory failure, coma and other critical illnesses. Flow diagrams for the literature selection are shown in Figure 1. The study characteristics are shown in Tables 1-2.

Meta-Analysis of laryngeal masks vs endotracheal intubation in manikin studies

Overall intubation success rate

A total of 8 randomized studies [8, 10-16] reported overall intubation success rates. No statistical heterogeneity was observed ($P=0.939$, $I^2 = 0.0\%$) so a fixed effect model was employed. The results showed that the overall intubation success rates of the laryngeal mask group were significantly higher than those of the endotracheal intubation group [$RR=1.10$, 95% CI (1.02, 1.18), $P<0.001$] (Figure 2).

Success rates of first intubation

A total of 4 randomized studies [8, 11, 13, 16] reported the success rates of the initial intubation. There was statistical heterogeneity ($P = 0.000$, $I^2 = 73.2\%$) so a random effects model was used. The result showed that the success rates of the initial intubation of the laryngeal mask group were significantly higher than those of the endotracheal intubation group [$RR=1.25$, 95% CI (1.01, 1.55), $P<0.001$] (Figure 3).

Insertion time

Eight randomized studies [9–16] reported differences in the insertion times. A random effects model was used for statistical heterogeneity ($P = 0.000$, $I^2 = 88.7\%$). The results showed significantly shorter insertion times of the laryngeal mask group [$SMD=-1.53$, 95% CI (-1.88, -1.17), $P < 0.001$] (Figure 4).

Meta-Analysis of laryngeal mask vs endotracheal intubation in human studies

Ventilation efficiency rates

Meta-analysis of 17 randomized studies [17-23, 27-29, 32, 34, 36, 38-40, 42] showed that the ventilation efficiency rates of the laryngeal mask groups were higher than those of the endotracheal intubation groups [$RR=1.20$, 95% CI (1.06, 1.35), $P<0.001$] without heterogeneity ($P = 0.941$, $I^2 = 0\%$) (Figure 5).

Overall intubation success rates and rates of initial intubation

A total of 19 [17, 20-23, 25, 28-29, 33-37, 39-42, 44-45] and 3 randomized studies [35, 41, 46] reported the success rates of initial intubation and overall intubation success rates, respectively. The results suggested that the success rates of initial intubation for the laryngeal mask were higher than those for endotracheal intubation [$RR=1.29$, 95% CI (1.18, 1.40), $P<0.001$] without heterogeneity ($P = 0.840$, $I^2 = 0\%$). However, no statistical differences in overall intubation success rates were observed [$RR=1.11$, 95% CI (0.88, 1.39), $P<0.001$] without heterogeneity ($P = 0.979$, $I^2 = 0\%$) (Figure 6).

Insertion time and SpO₂ rise time

A total of 27 [17, 20-31, 33-37, 39-47] and 3 studies [17, 20, 33] reported insertion and SpO₂ rise times, respectively. The results suggested that both were shorter in the laryngeal mask groups compared to endotracheal intubation [SMD=-3.48, 95% CI (-4.17, -2.80), $P < 0.001$; -2.19, 95% CI (-3.06, -1.32), $P < 0.001$] but with significant heterogeneity ($P = 0.000$, $I^2 = 96.8\%$; $P = 0.001$, $I^2 = 85.5\%$) (Figure 7).

Blood gas index

Three studies [19, 32, 37] reported PaCO₂, PaO₂ and pH, and 8 studies [19, 23, 25-26, 32, 37, 44, 47] reported SpO₂. The pooled results showed that laryngeal mask ventilation increased pH [SMD=3.74, 95% CI (0.68, 6.80), $P < 0.001$, $I^2 = 97.4\%$], PaO₂ [SMD=2.93 95% CI (1.43, 4.42), $P < 0.001$, $I^2 = 91.4\%$] and SpO₂ [SMD=1.07, 95% CI (0.11, 2.04), $P < 0.001$, $I^2 = 95.8\%$] and lowered PaCO₂ [SMD=-4.03, 95% CI (-5.32, -2.73), $P < 0.001$, $I^2 = 83.1\%$] (Figure 8).

Subgroup analysis

Due to the existence of heterogeneity, we performed subgroup analysis on the initial success rates of the first insertion and insertion time. As shown in Table 3, we failed to identify any source of heterogeneity in insertion times across the human studies.

Sensitivity analysis and publication bias

The results of sensitivity analysis and publication bias are shown in Table 4. Funnel plots of manikin and human studies are shown in Figures 9-10, respectively. Sensitive analysis suggested that all the results were stable. Egger's tests showed the presence of publication bias in the ventilation efficiency rates and insertion times of human studies, but metatrim suggested that the bias had no influence on the final results.

Discussion

To our knowledge, this is the first systematic review and meta-analysis to compare the clinical effects of laryngeal masks and endotracheal intubation from manikins and humans for pre-hospital emergencies. Our study showed that for both manikin and human studies, the overall effects of the laryngeal mask ventilation were superior to endotracheal intubation. Sensitivity analysis and publication bias tests also suggested that the results were stable and reliable.

Laryngeal masks have unique advantages for clinical applications, including ease of use and the ability to rapidly maintain the airways. Even when the position of the laryngeal mask was not ideal, it can maintain airway patency [48]. A secondly advantage is that no laryngoscopes are needed. Compared to endotracheal intubation, it is easy for beginners to insert the laryngeal mask and the success rates are relatively high [49]. Thirdly, the laryngeal mask is used as a supraglottic ventilation device, which has the advantage of establishing the airways for autonomous ventilation and ventilation control, thus avoiding mucosal damage in the trachea. Ventilation management through endotracheal intubation is not satisfactory. Cobas et al [50]

reported that the failure rates of non-anesthesiologists for endotracheal intubation can be as high as 31%. Even with experienced clinicians, the misalignment rates were as high as 17.4. %, of which the esophageal insertion rates were 6.7% [51]. This can be fatal for comatose patients.

Our meta-analysis showed that the success rates of first-pass intubation in the laryngeal mask group were significantly higher than the control group, and the time taken for laryngeal mask placement was significantly shorter. These results indicate that the laryngeal mask had improved success rates for first-pass intubation. Unlike blind tracheal tube placement, the use of a laryngeal mask does not involve glottis exposure, is easy to operate, and easy to master. Furthermore, its shorter placement times are beneficial to the early recovery of the patient's ventilator function. Hypoxia in the brain tissue for more than 5 minutes can lead to irreversible brain damage; thus, establishing airway ventilation as early as possible is key to successful cardiopulmonary resuscitation. Brimacombe et al [52] reported that medical staff without experience in laryngeal mask placements were more likely to insert laryngeal masks with shorter insertion times, which was similar to our subgroup analysis. The clinical medical students of the included studies had no experience in the use of laryngeal masks, and some nurses and EMT lacked systematic training. The laryngeal mask insertion time was however shorter than that of endotracheal intubation. Subgroup analyses also suggested that paramedics, anesthesiologists, nurses, and emergency physicians have shorter insertion times for laryngeal masks in both stationary and mobile environments. The success rates of initial intubation and insertion time in the laryngeal mask groups were superior to the endotracheal intubation groups, further demonstrating the advantages of the laryngeal mask. The application of the laryngeal mask in pre-hospital emergency patients benefits the early recovery of tracheal ventilation, and promotes the success of cardiopulmonary resuscitation. The drawbacks include the lack of data in the included studies.

Laryngeal mask ventilation also improved the blood gas index, leading to higher levels of PaO₂ and SpO₂ and shorter SpO₂ rise times, which are important to ensure good patient prognosis.

The included manikin studies were randomized crossover trials, and the risk of bias was primarily in the blinding method, which could not be implemented. Due to the small sample size, we performed Egger's tests. The results showed that the small sample effect did not influence the final data outcomes. Moreover, specific information of the human studies was unknown due to random grouping.

The study had some limitations. First, the quality of the evidence in the included studies was weak. Secondly, the sources of heterogeneity for the comparison of first intubation success rates and insertion times were not clearly identified. Thirdly, we failed to study the different methods of laryngeal masks and endotracheal intubation. Moreover, the update of the laryngeal mask was rapid with standard types, intubable types, esophageal drainage types and no cuff types. The application of these different laryngeal masks in pre-hospital emergencies also requires further exploration. Finally, the included data were inadequate, so specific subgroup analysis regarding the participants identity in the overall intubation success rate was not conducted.

Conclusions

In summary, laryngeal masks could quickly and effectively improve patient ventilation compared to endotracheal intubation. Laryngeal masks are therefore a more effective ventilation device and should be employed in pre-hospital emergencies. Further high-quality randomized controlled trials are now required to further demonstrate the reliability of our conclusions.

Abbreviations

Emergency medical technician, EMT; Laryngeal mask airway, LMA; Endotracheal intubation, EI; Mean standard difference, SMD; Interquartile range, IQR; Standard difference, SD; Risk ratio, RR; Confidence interval, CI.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

Competing interests

There is no competing interests for publication of this paper.

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Authors' contributions

JB. C and H. L had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. JB. C and MD. D conceived and designed the study; YX. S, X. Z, M. L, WG. L and AS. H led the acquisition, analysis, or interpretation of data; H. L and MD. D drafted the manuscript, YL. Z and SH. Y, checked this work again. All authors read and approved the final manuscript.

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Tables

Table 1. Characteristics of manikin studies

Author, year	Country	Group	Number	Participants	Outcomes	Jada scores	Notes
A Timmermann, 2007 ⁸	Germany	LMA	119	Medical students	A, B	5	Stationary environment
		ET	119				
A Wolfgang, 2015 ⁹	Germany	LMA	25	Anaesthesiologists	C	4	Stationary environment
		ET	25				In the scenario with access through the opened driver's door to the simulated trapped car victim
C Voscopoulos, 2012 ¹⁰	USA	LMA	41	EMT	A, C	4	Stationary environment
		ET	42				
I Shavit, 2015 ¹¹	Israel	LMA	29	EMT	A, B, C	5	Stationary environment
		ET	29				
S Rosa, 2018 ¹²	Italy	LMA	47	Anesthesia, nurses, intensive care and emergency physicians	A, C	6	Stationary environment
		ET	47				
D Steinmann, 2016 ¹³	Netherlands	LMA	25	Paramedics	A, B, C	5	Stationary environment
		ET(Macintosh)	25				In the scenario with access through the opened driver's door to the simulated trapped car victim
		ET(Airtraq)	25				
		LMA	25	Emergency physicians	A, B, C		Paramedics: a, LMA vs ET(Macintosh); b, LMA vs ET(Airtraq); Emergency physicians: c, LMA vs ET(Macintosh); d, LMA vs ET(Airtraq);
		ET(Macintosh)	25				Stationary environment
		ET(Airtraq)	25				
		LMA	25	Paramedics	A, B, C		In the scenario with access from the back seat to the simulated trapped car victim
		ET(Macintosh)	25				
		ET(Airtraq)	25				
		LMA	25	Emergency physicians	A, B, C		Paramedics: e, LMA vs ET(Macintosh); f, LMA vs

		ET(Macintosh)	25				ET(Airtraq); Emergency physicians: g, LMA vs ET(Macintosh); h, LMA vs ET(Airtraq);
		ET(Airtraq)	25				a, LMA vs ET (paramedics)
M Saeedi, 2014 ¹⁴	Iran	LMA	16	Paramedics	A, C	6	b, LMA vs ET (EMT)
		ET	16				c, LMA vs ET (anaesthesiologists)
		LMA	27	EMT	A, C		d, LMA vs ET (nurses)
		ET	27				
		LMA	8	Anaesthesiologists	A, C		
		ET	8				
		LMA	8	Nurses	A, C		
		ET	8				
O Karaca, 2017 ¹⁵	Turkey	LMA	38	Paramedics	A, C	5	Stationary environment
		ET with GEB	38				a, LMA vs ET with GEB
		ET with Classic Stylet	38				b, LMA vs ET with Classic Stylet
		LMA	38	Paramedics	A, C		Moving environment
		ET with GEB	38				c, LMA vs ET with GEB
		ET with Classic Stylet	38				d, LMA vs ET with Classic Stylet
							Stationary environment
							a, ProSeal LMA vs ET
SJ Park, 2016 ¹⁶	Korea	ProSeal LMA	109	Medical students	A, B, C	5	b, I-gel LMA vs ET
		I-gel LMA	109				
		ET	109				

GEB, gum elastic bougie; EMT, emergency medical technicians; A, overall intubation success rate; B, success rate of first intubation; C, insertion time.

Table 2. Characteristics of human studies

Author, year	Country	LMA(n)	ET(n)	Outcomes	Jada scores
Y Ding, 2016 ¹⁷	China	40	40	B, C, D, E	4
JC Gou, 2017 ¹⁸	China	40	40	D	4
J Gao, 2015 ¹⁹	China	41	41	D, F, G, H, I	4
XM Huang, 2016 ²⁰	China	40	40	B, C, D, E	4
PL Li, 2018 ²¹	China	47	47	B, C, D	4
JS Liu, 2017 ²²	China	34	34	B, C, D	4
P Long, 2018 ²³	China	47	45	B, C, D, I	4
JJ Lu, 2012 ²⁴	China	41	50	C	5
G Qin, 2017 ²⁵	China	27	27	B, C, I	5
GJ Qiu, 2018 ²⁶	China	15	15	C, I	4
DZ Shi, 2018 ²⁷	China	90	90	C, D	5
DJ Sun, 2017 ²⁸	China	30	30	B, C, D	4
H Tang, 2018 ²⁹	China	20	20	B, C, D	4
XM Tang, 2017 ³⁰	China	82	100	C	4
XQ Tu, 2018 ³¹	China	45	45	C	4
Q Wang, 2017 ³²	China	20	20	D, F, G, H, I	4
H Yan, 2017 ³³	China	35	35	B, C, E	4
YZ Yuan, 2017 ³⁴	China	30	32	B, C, D	4
X Huang, 2013 ³⁵	China	25	25	A, B, C	4
H Li, 2013 ³⁶	China	99	84	B, C, D	5
J Liang, 2016 ³⁷	China	30	30	B, C, F, G, H, I	4
ZM Liang, 2016 ³⁸	China	28	28	D	4
JH Sha, 2011 ³⁹	China	35	30	B, C, D	4
Y Wu, 2014 ⁴⁰	China	40	40	B, C, D	5
FF Xia, 2013 ⁴¹	China	18	18	A, B, C	4
DM Yang, 2011 ⁴²	China	28	28	B, C, D	4
Y Yang, 2016 ⁴³	China	30	30	C	4
L Zhou, 2013 ⁴⁴	China	96	104	B, C, I	5
XH Zhou, 2016 ⁴⁵	China	73	79	B, C	4
CD Deakin, 2005 ⁴⁶	Iran	52	52	A, C	5
S Khosravan, 2015 ⁴⁷	UK	18	17	C, I	4

A, overall intubation success rate; B, success rate of first intubation; C, insertion time; D, ventilation efficiency rate; E, SpO2 rise time; F, PaCO2; G, PaO2; H, pH; I, SpO2.

Table 3. Results summary for subgroup analysis in manikin and human studies

Subgroup (effect size)	Number	Effect value	Heterogeneity	
			I ²	P
Manikin studies				
Success rate of first insertion (risk ratio)				
Environment				
Stationary	282	1.37 [1.02, 1.83]	99	0.0001
Moving	-	-	-	-
Participants				
Medical students	228	3.15 (1.50, 6.62)	94	0.0001
EMT	29	1.50 (1.11, 2.03)	-	-
Insertion time				
(mean standard difference)				
Environment				
Stationary	109	-1.51 (-1.90, -1.12)	89	0.0001
Moving	38	-1.43 (-2.01, -0.85)	61	0.11
Participants				
Medical students	109	-1.74 (-2.51, -0.97)	92	0.0005
Anaesthesiologists	34	-1.49 (-2.04, -0.94)	0	0.62
Paramedics	34	-1.51 (-1.88, -1.14)	70	0.001
Nurses	8	-2.02 (-3.29, -0.75)	-	-
Emergency physicians	25	-2.15 (-2.50, -1.79)	0	0.58
Human studies				
Insertion time				
(mean standard difference)				
Cause				
Cardiac arrest	632	-4.01 (-5.60, -2.53]	97.2	0.000
Respiratory failure	405	-4.26 (-5.45, -3.06)	91.0	0.000
Coma	420	-1.96 (-2.81, -1.12)	91.3	0.000
Year				
≤50	800	-3.11 (-4.12, -2.10)	95.8	0.000
>50	1017	-4.19 (-5.44, -2.95)	97.4	0.000

EMT, emergency medical technicians.

Table 4. Results summary for sensitive analysis after changing effect model and publication bias (Egger's test)

Sensitive analysis	Effect size	[Effect value(95%CI), P]	Egger's test(P)
Manikin studies			
Overall intubation success rate	RR	[1.11 (1.03, 1.19), 0.006]	0.879
Success rate of first intubation	RR	[1.38 (1.23, 1.54), 0.000]	0.929
Insertion time	SMD	[-1.41(-1.52, -1.30), 0.000]	0.346
Human studies			
Ventilation efficiency rate	RR	[1.18(1.04, 1.32), 0.007]	0.001
Success rate of first intubation	RR	[1.27(1.16, 1.38), 0.000]	0.089
Insertion time	SMD	[-2.46(-2.58, -2.34), 0.000]	0.000

Figures

Figure 1

Flow diagram for the literature selection

Figure 2

Forest plot of overall intubation success rates in the manikin studies

Figure 3

Forest plot of success rates of the initial intubation in the manikin studies

Figure 4

Forest plot of the insertion time in the manikin studies

Figure 5

Forest plot of the ventilation efficiency rates in the human studies

Figure 6

Forest plot of the overall intubation success rate and success rate of the initial intubation in the human studies

Figure 7

Forest plot of the insertion time and SpO2 rise time in the human studies

Figure 8

Forest plot of the blood gas index in the human studies

Figure 9

Funnel plots of overall intubation success rates (A), success rates of initial intubation (B) and insertion times (C) in the manikin studies.

Figure 10

Funnel plots of ventilation efficiency rates (A), success rates of initial intubation (B) and insertion times (C) in the human studies.

Supplementary Files

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- [PRISMA2009checklist.pdf](#)