Original Article

A systematic review and meta-analysis of different mask ventilation schemes on management of general anesthesia in patients with respiratory failure

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Background: Difficulty in mask ventilation is one of the more dangerous factors in general anesthesia. The traditional mask has some problems, such as air leakage and facial skin compression injury. The head cover is a new interactive non-invasive ventilation (NIV) model. NIV studies comparing hoods and masks have all been single-center and small-sample randomized trials, and extensive clinical studies are lacking.

Methods: We conducted a computerized search in the databases of PubMed, Embase, Medline, Chinese Biomedical Literature (CBM), and others for randomized controlled trials (RCTs) on the effect of hoods and masks on patients with respiratory failure published since their establishment to March 2021. The quality of the included literature was assessed using the Cochrane Systematic Review Manual, and the data was analyzed using Review Manager 5.3 to assess the risk of bias.

Results: A total of 9 articles were included, involving 462 patients, with 233 patients in the hood group and 229 patients in the face mask group. The results of meta-analysis showed the comparative endotracheal intubation rate of the hood group and the mask group [odds ratio (OR) =0.26; 95% confidence interval (CI): 0.14 to 0.47; Z=4.48; P<0.00001], the complications rate (OR =0.54; 95% CI: 0.31 to 0.97; Z=2.08; P=0.04) was statistically considerable, although there was no considerable difference in in-hospital mortality (OR =0.56; 95% CI: 0.28 to 1.14; Z=1.59; P=0.11).

Discussion: NIV with a hood can reduce the rate of endotracheal intubation and the incidence of related complications in patients with acute respiratory failure (ARF), which has considerable advantages in contrast to the traditional mask.

Keywords: Hood; mask; respiratory failure; non-invasive ventilation (NIV); meta-analysis

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Introduction

The difficulty involved with mask ventilation is one of the risk factors in general anesthesia. Issues with mask ventilation often occur during anesthesia or emergency treatment of critical patients, and the identification and assessment of such difficulties is very important to the prognosis of patients. Mechanical ventilation is the first-line treatment for respiratory failure from various causes, which is classified into non-invasive and invasive methods (1). Non-invasive ventilation (NIV) is a breathing support technology that does not require the establishment

of an artificial airway. NIV is a safe and effective way of ventilation for patients with acute respiratory failure (ARF) who have a clear consciousness and can cooperate with the operation (2). However, NIV is difficult to reverse pulmonary encephalopathy in the short term, and the delay in the timing of intubation will increase the mortality rate. Therefore, in the short-term emergency treatment or facing unconscious patients, invasive ventilation is needed (3). Under anesthesia, due to the relaxation and collapse of the hypertrophic tongue and throat, combined with hypertrophy of the respiratory tract, stenosis of the lumen, and the effect on lung function, respiratory tract obstruction is can easily occur. The respiratory tract is extremely difficult to manage, and the associated disability and mortality rates are 3 times higher than normal. Even small changes in the flow of gas through the pharynx play a crucial role. Traditional masks are prone to air leakage, facial skin compression injury, patient intolerance, and so on, which often lead to the failure of non-invasive mechanical ventilation and the need for endotracheal intubation (4,5). NIV usually requires the use of a nasal mask or face mask to connect the ventilator and the patient. However, despite the optimization of the material and shape of the mask, it will still cause facial skin damage, air leakage or difficulty in expectoration, so the NIV failure rate is as high as 18% (6). The new hood can effectively solve the above-mentioned shortcomings, and compared with the face mask, the patient has better tolerance and low complication rate (7). Research has shown that hood can reduce the rate of intubation and extend the benefits of NIV to more patients with acute respiratory distress syndrome (8).

At present, studies comparing the NIV types of hood and mask have all been single-center and small-sample randomized trials. There are relatively few studies using a large sample size to comprehensively analyze and compare the effects of ventilation treatment between hoods and face masks. In order to make up for this shortcoming, the safety and effectiveness of mask-type NIV in the treatment of patients with respiratory failure are evaluated. This article uses meta-analysis to explore the difference between the reintubation rate and complication rate of patients after hood and face mask treatment. It is expected to provide a basis for the clinical treatment of patients with respiratory failure and to improve the treatment effect of patients. We present the following article in accordance with the PRISMA reporting checklist (available at https://dx.doi.org/10.21037/apm-21-2709).

Methods

Literature inclusion and exclusion criteria

The inclusion criteria for related research were as follows: (I) clinical randomized controlled trial (RCT); (II) participants were adults with ARF; (III) clinical study comparing hood NIV and mask NIV; (IV) the study group (hood group) and the control group (mask group) were treated basically the same except for hood or mask ventilation.

The exclusion criteria were as follows: (I) duplicate publications; (II) literature that was not a clinical RCT, such as reviews, meetings, and case reports; (III) literature in which the participants were minors; (IV) literature with incomplete full text and data.

Literature searching

The databases of PubMed, Embase, Medline, Chinese Biomedical Literature (CBM), and others were searched by computer from their inception to March 2021. The search terms were “helmet”, “face mask”, “facial mask”, “noninvasive ventilation”, “respiratory failure”, and so on. The best combination of the above phrases was used to enable the maximum amount of relevant literature to be obtained. Some references of the included literatures were further searched, and the full text was manually retrieved and included in this study. After the retrieval, qualified clinical RCTs were screened according to inclusion and exclusion criteria for meta-analysis.

Literature searching and data extraction

The literature was first screened by two researchers according to the title and abstract of the literature, and they then further screened the full text according to the same inclusion and exclusion criteria. In the case of disagreement, resolution was sought through discussion, and if the discussion remained unresolved, a third researcher was assigned the task of arbitration. The information extracted from the literature included the first author, year of publication, mean age, number of cases of each group of participants, participant characteristics, and outcome indicators, as well as the rate of endotracheal intubation, mortality, and length of intensive care unit (ICU) stay in each group after treatment. The process of information extraction was also completed by two researchers independently and cross-checked. In case of disagreement,

the third researcher was invited to participate in the discussion and make a decision.

Literature bias risk and methodological quality evaluation

The Cochrane randomized trial risk assessment tool (9) was used to assess the quality of the literature, including six items: (I) the generation method of random sequences; (II) whether there was bias in the distribution process; (III) whether the researcher used blind method; (IV) blind evaluation of research results; (V) whether the result data were complete; (VI) whether the results were selectively reported; (VII) other offsets. Each evaluation index was classified into three grades: low risk of bias, high risk of bias, or unclear risk of bias.

Statistical methods

Review Manager 5.3 (RevMan; Copenhagen, The Nordic Cochrane Center, The Cochrane Collaboration, 2014) was used for statistical analysis of the data. The relative risk ratio (RR) was calculated for the dictation variable, and 95% confidence interval (CI) was used for each effect size. The main methods of sensitivity analysis are: changing the inclusion criteria, excluding low-quality studies, using different statistical methods/models to analyze the same data, etc. After excluding a low-quality study, re-estimate the combined effect size and compare it with the results of the meta-analysis before the exclusion to discuss the extent of the study's influence on the combined effect size and the robustness of the results. According to the results of statistical heterogeneity testing, the combined effects model was selected. If the study effect size was homogeneous (I^2<50%), the fixed effects model was adopted. If the effect size showed heterogeneity (I^2≥50%), the random effects model was used. Funnel plot was used to evaluate publication bias of literature. If the funnel plot was symmetrical, low publication bias was indicated; otherwise, large publication bias was inferred.

Results

Literature retrieval and feature analysis

Literature was included based on the Cochrane systematic retrieval strategy. The search keywords were set as "helmet", "face mask", "facial mask", "noninvasive ventilation", and "respiratory failure". A total of 893 literatures were obtained in the preliminary examination, and repeated literatures were excluded. The titles and abstracts of articles were carefully read. Non-clinical trials, such as reviews, those conducted on animals and minors, and meta-analyses were excluded. After reading of full texts, research with unclear explanation and incomplete data was excluded, as were case control studies, and those with unclear grouping. Finally, total of 9 articles were included (10-18), involving 462 patients, with 233 patients in the hood group and 229 patients in the face mask group. The flow chart of literature retrieval and screening is shown in *Figure 1*, and the basic information of the included literature is shown in *Table 1*.

Included literature quality evaluation

The bias risk assessment tool of Review Manager 5.3 was used to evaluate the quality of the 9 included literatures, and the results are shown in *Figures 2,3*. Most aspects of the included RCTs were assessed as having a low risk of bias. Due to the characteristics of hood and mask used *in vitro*, it was difficult to blind researchers and participants during the process. Therefore, blinding of participants and personnel (performance bias) included in this study were assessed as high risk. The integrity of the data and the selectivity of the report were classified as low risk.

Results of meta-analysis

Endotracheal intubation rate

All 9 articles included in this study reported the patient's tracheal intubation rate, and compared the difference in tracheal intubation rate between the hood group and mask group. The results of comparison are shown in *Figure 4*. The tracheal intubation rates of the hood group and face mask group were 7.73% (18/233) and 21.83% (50/229), respectively. The heterogeneity test indicated that no heterogeneity was found in the study effect size (I^2=0%; P=0.52), so the fixed effects model was used. Meta-analysis results showed that the effective effect value of the experimental group and the control group was odds ratio (OR; 95% CI) =0.26 (0.14 to 0.47). The horizontal line fell on the left side of the invalid vertical line, the statistical test result was Z=4.48, P<0.00001, the difference was considerable (P<0.05). The incidence of tracheal intubation in the hood group was 34% of the mask group, indicating that the use of hood can reduce the patient's tracheal

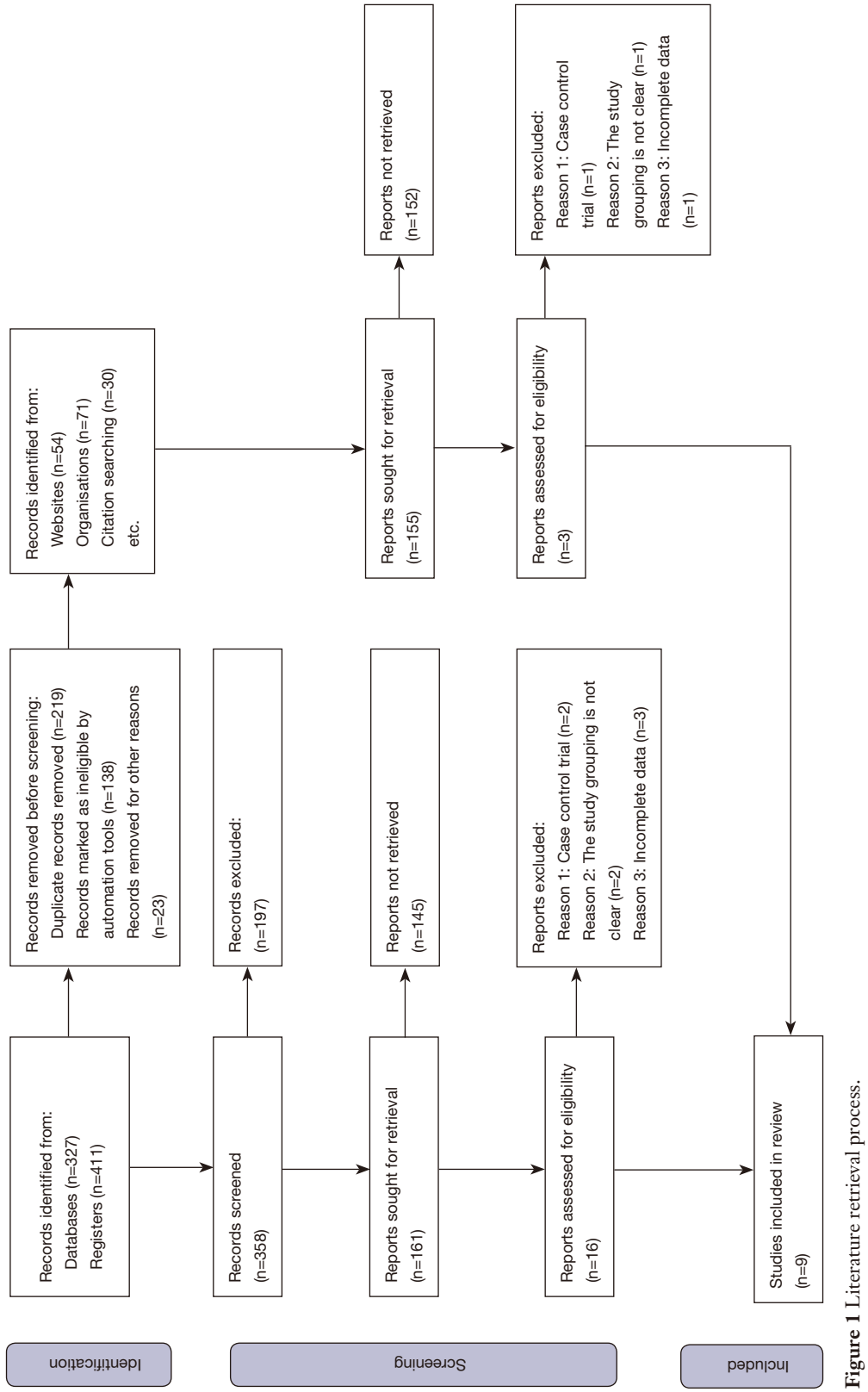

Figure 1 Literature retrieval process.

Table 1 Basic characteristics of the included literature

First author	Year	Age (mean ± variance)		Gender (male/female)		Number of samples		Participant types	Outcome indicators
		Hood group	Mask group	Hood group	Mask group	Hood group	Mask group		
Patel (10)	2016	58.0	60.9	24/20	21/18	44	39	Acute respiratory distress syndrome	Intubation rate, hospital mortality, length of stay in ICU, adverse reactions, length of NIV, respiratory rate
Liu (11)	2020	49.24±14.20	49.06±15.90	23/6	27/3	29	30	ARF caused by chest trauma	Intubation rate, hospital mortality, complications, blood gas analysis
Özlem (12)	2015	69.5±7.41	64.3±10.1	6/19	8/15	25	23	Acute exacerbation of chronic obstructive pulmonary disease	Intubation rate, hospital mortality, complications, blood gas analysis, length of stay in ICU, length of NIV
Antonaglia (13)	2011	69	71	–	–	20	20	Acute exacerbation of chronic obstructive pulmonary disease	Intubation rate, blood gas analysis, duration of NIV, length of stay in ICU, respiratory rate
Pisani (14)	2015	78.36±10.58	78.48±7.75	–	–	39	41	Chronic obstructive pulmonary disease with hypercapnia	Intubation rate, adverse reactions, respiratory rate, heart rate
Ali (15)	2011	59.4±6.8	58.5±5.8	–	–	15	15	Acute exacerbation of chronic obstructive pulmonary disease	Intubation rate, complications, blood gas analysis, length of stay in ICU
Yang (16)	2015	52.7±8.9	55.5±8.6	13/7	12/8	20	20	Hypoxemia after aortic dissection	Intubation rate, hospital mortality, complications, blood gas analysis, length of stay in ICU, respiratory rate, heart rate
Cuvelier (17)	2009	77.8±8.9	70.0±12.0	12/5	13/4	17	17	Acute hypercapnic respiratory failure	Intubation rate, hospital mortality, length of stay in ICU, blood gas analysis, respiratory rate, complications
Sadeghi (18)	2017	63.21±10.22	67.83±6.46	13/11	15/9	24	24	ARF	Intubation rate, hospital mortality, length of stay in ICU, length of NIV, respiratory rate

ICU, intensive care unit; NIV, non-invasive ventilation; ARF, acute respiratory failure.

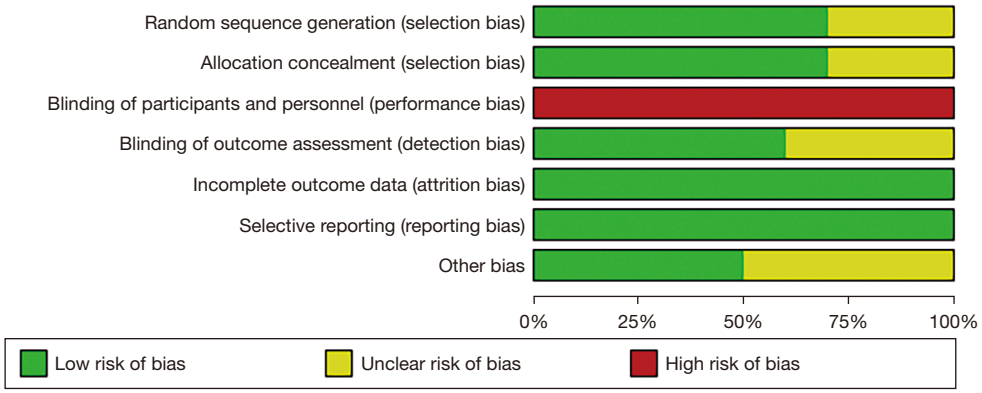

Figure 2 Bar charts of inclusion bias risk assessment.

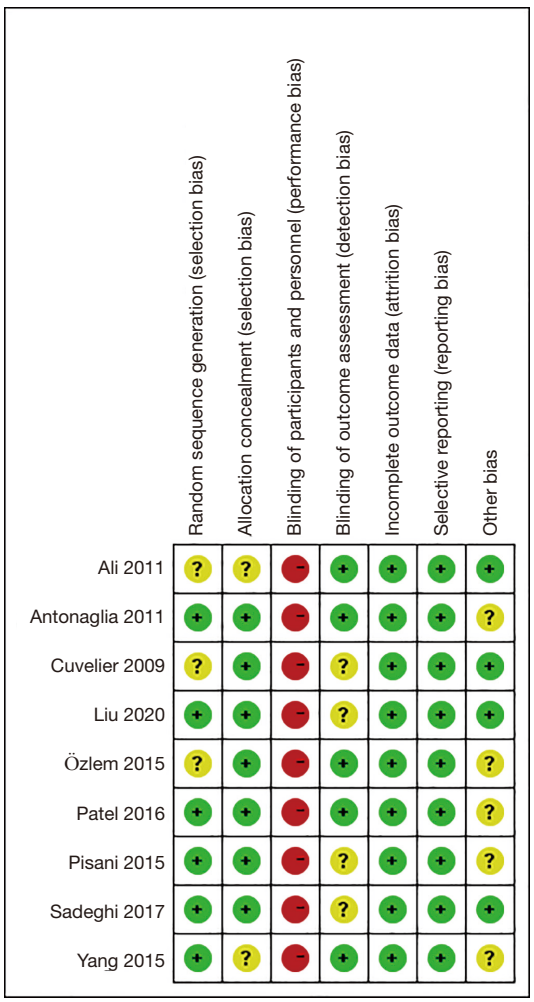

Figure 3 The bias evaluation of the included literature.

intubation rate.

Complication rate

A total of 5 articles reported the occurrence of complications and compared the difference in the incidence of complications between the hood group and the mask group, and the results of comparison are shown in *Figure 5*. The complication rates of the hood group and mask group were 17.53% (27/154) and 27.33% (41/150), respectively. The heterogeneity test indicated no heterogeneity in the study effect size (I^2<50%; P=0.12), so the fixed effects model was used. Meta-analysis results showed that the effective effect value of the experimental group and the control group was OR (95% CI) =0.54 (0.31 to 0.97). The horizontal line fell on the left side of the invalid vertical line, the statistical test result was Z=2.08, P=0.04, and the difference was considerable (P<0.05), indicating that the complication rate of the hood group was lower than that of the mask group.

In-hospital mortality rate

A total of 6 articles in the included literature reported in-hospital mortality. The difference between the in-hospital mortality of the hood group and the mask group was compared, and the results are shown in *Figure 6*. The in-hospital mortality of the hood group and face mask group were 11.32% (18/159) and 16.34% (25/153), respectively. The heterogeneity test indicated no heterogeneity in the study effect size (I^2=0%; P=0.91), so the fixed effects model was used. Meta-analysis results showed that the effective rate of the experimental group and the control group was

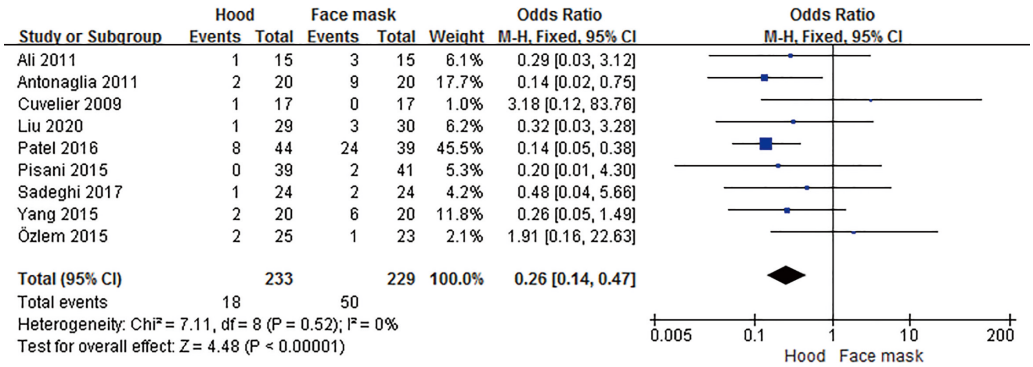

Figure 4 Forest plot of endotracheal intubation rate.

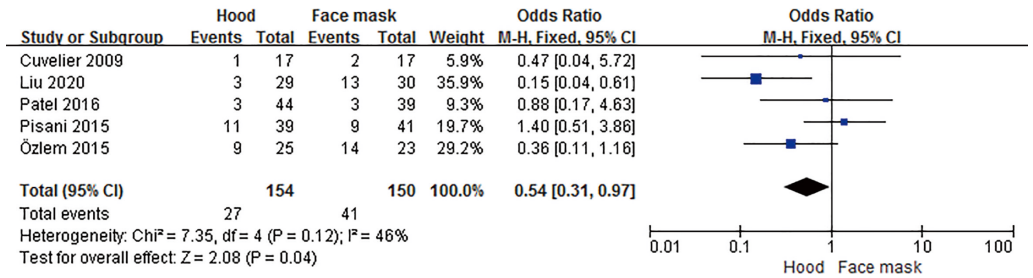

Figure 5 Forest plot of complication rate.

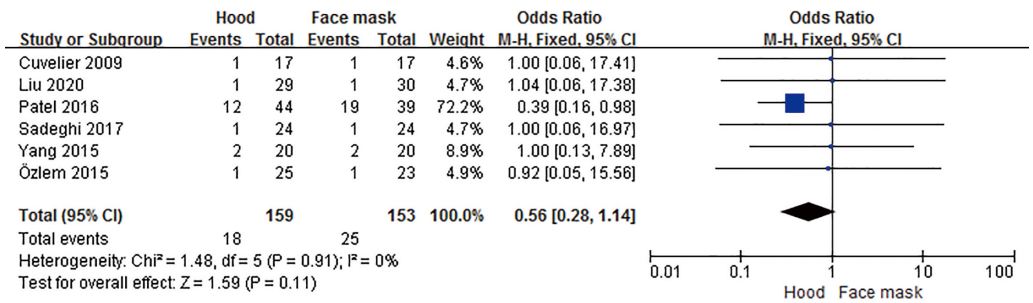

Figure 6 Forest map of in-hospital mortality.

OR (95% CI) =0.56 (0.28 to 1.14). The horizontal line fell to the left of the invalid vertical line, the statistical test result was Z=1.59, P=0.11, and the difference was not considerable (P>0.05).

Publication bias analysis

The tracheal intubation rate and the in-hospital mortality rate were plotted to make a funnel chart to determine whether there was publication bias in the literature. The results are shown in *Figures 7,8*. The graphs were asymmetric, but they all fell within the credible interval, and they were basically close to the central axis.

Discussion

The primary task of clinical anesthesia is keeping the patient's airway unobstructed and ensuring effective ventilation (19). For supine patients, there are many factors affecting whether the tongue or soft palate obstructs pharyngeal ventilation. The first factor is gravity, which is the most important and most overlooked

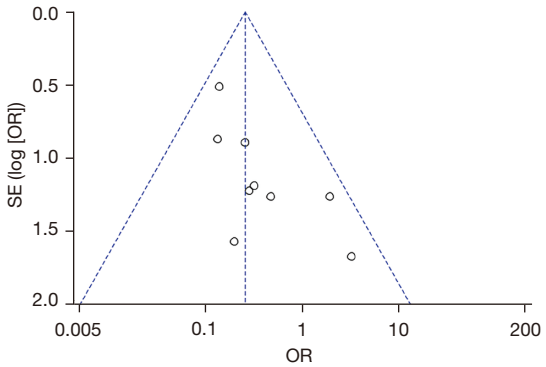

Figure 7 Publication bias funnel plot of endotracheal intubation rate.

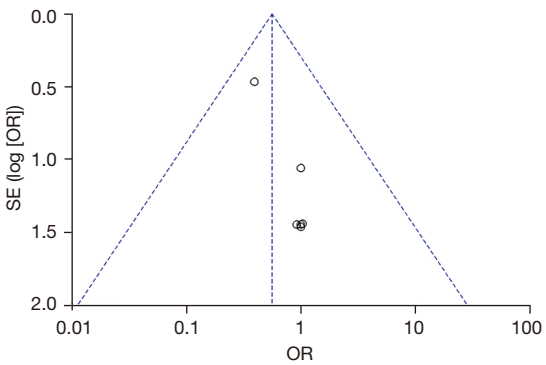

Figure 8 Publication bias funnel plot of in-hospital mortality.

factor (20). Especially, when muscle relaxants are used during anesthesia, there is no effect of the muscles themselves. The second is the additional downward pressure exerted on the tongue and soft palate by the positive airway pharyngeal airflow of the mask and the upward pressure exerted on the tongue and soft palate by the nasopharyngeal airflow. Pharynx gas flow mainly depends on the three pressure differences. Normally, breathing gas enters the laryngeal glottis in two ways: the first is nostril, which travels from the nasopharynx to the larynx. The second is oral cavity, which is between the palate and tongue to oropharynx, laryngeal pharynx, and glottis. The incidence of cardiac arrest due to difficulty in airway management during general anesthesia is as high as 50–75% (21). In clinical practice, difficulty in airway management is often understood as difficulty in endotracheal intubation due to the low incidence of difficulty in mask ventilation (22). In nearly 20 years of clinical practice, non-invasive mechanical ventilation has been widely used, which can avoid tracheal intubation to a certain extent. The method of NIV provides patients with respiratory support through a non-invasive interface, which can maintain patients' swallowing and expectoration ability and reduce the incidence of ventilators associated with pneumonia (23,24). However, non-invasive mechanical ventilation is often interrupted due to patient intolerance, leading to treatment failure (25). The cause of interruption may be related to the human-computer interaction of NIV. The classic human-computer interaction is mask-style, which requires a certain amount of pressure to maintain the mask close to the patient's facial skin to reduce air leakage. The disadvantage is that after long-term use, facial skin is prone to compression and redness, forming ulcers and eye irritation (26-28). To improve patients' tolerance to mechanical ventilation, a new hood type human-computer interaction has emerged. Compared with the mask type, the hood is suitable for patients with various face types, and it does not affect the patient's contact and communication with the surrounding environment in the process of treatment. The patient's muscles and jaw joint are relaxed. Air-tightness is a requirement for the mask, and the mandible must be supported for good ventilation, whereas hood ventilation does not require such support (29). Mask NIV can cause a variety of complications, discomfort and poor tolerance (30). Studies have shown that predictive provision of corresponding nursing intervention can significantly reduce the complications caused by NIV and improve the treatment effect of patients (31).

In this study, 10 RCTs were included for meta-analysis. The results found that in contrast to mask NIV, hood NIV can statistically reduce NIV complications and can reduce the frequency of respiratory failure and tracheal intubation rate. Although the hospital mortality rate in the hood group was lower than that in the mask group (9.78% *vs.* 14.61%), the difference was not considerable (P>0.05). The reason for the remarkably lower tracheal intubation rate may have been the effective delivery of higher positive end-expiratory pressure, which may be related to the unique advantages of the hood. First, the hood allows the patient's head to move relatively freely, while maintaining a good seal, and will not oppress the face or head, which can reduce complications such as skin necrosis and improve patient comfort. It enables patients to tolerate the mask well and further extends the application time of NIV, which is also a decisive factor for the success of NIV. Secondly, the hood is not limited to the face shape of the patient and can be used in the case of abnormal facial anatomy, such as edentulous and facial trauma patients. Third, the patient can interact

with the surrounding environment through the transparent cover. However, studies have found that the noise of the hood was remarkably greater than that of the mask and may impair the function of the ears. In the included literature, study of Pisani *et al.* (14) found that the hood may cause claustrophobia, which was not a complication of the mask. The patient had good tolerance to the hood, and the hood had the characteristics of good comfort and wide application range. Antonaglia *et al.* (13) found through RCTs that the incidence of intolerance of non-invasive mask ventilation in patients with acute exacerbation of chronic obstructive pulmonary disease was remarkably lower than that of non-invasive hood ventilation (5% *vs.* 40%, P<0.01). Chidini *et al.* (32) performed hood and mask ventilation therapy on infants and young children with respiratory failure caused by respiratory syncytial virus. The results showed that the intolerance rate and the failure rate of ventilation therapy in the hood group were remarkably lower than those in the mask group. Moreover, Yang *et al.* (16) randomly performed two types of NIV on patients with hypoxemia after coronary artery bypass grafting. The results also showed that the intolerance rate of the hood group was remarkably reduced, and the incidence of facial pressure ulcers and flatulence was remarkably lower than that of the mask group. However, Pisani *et al.* (14) found that in patients with acute exacerbation of chronic obstructive pulmonary disease, there was no difference in discomfort scores and adverse reactions between the hood group and the mask group. Avoiding tracheal intubation can reduce the incidence of ventilator-associated pneumonia and reduce the use of analgesic and sedative drugs. Antonaglia *et al.* (13) observed patients with acute exacerbation of chronic obstructive pulmonary disease and found that mask NIV can remarkably reduce the tracheal intubation rate than mask NIV. Further analysis showed that 88% of tracheal intubation failures in the mask group were caused by NIV intolerance. Compared with oxygen therapy, non-invasive mechanical ventilation can provide a certain amount of inspiratory pressure and positive end-expiratory pressure, thereby increasing the minute ventilation of the lungs, preventing alveolar collapse, reducing intrapulmonary shunt, increasing the ventilation/blood flow ratio, and promoting gas exchange.

In the process of research, it was found that the following deficiencies may have been the cause of bias: although all participants had symptoms of ARF, the causes of respiratory failure were different, such as respiratory failure after cardiovascular surgery, that caused by lung injury, and chronic obstructive pulmonary disease, which may have led to results bias. The number of included literatures was small, and the sample size of each study was relatively small. The characteristics of hood and mask make it difficult to apply the blind method, which may also have led to bias in the results.

Conclusions

To systematically evaluate the effects of different mask ventilation modes on the management of general anesthesia in patients with respiratory failure, a total of 10 related RCTs were included, and a meta-analysis of hood *vs.* mask for non-invasive mechanical ventilation was implemented. The results showed that the rate of endotracheal intubation and related complications in the hood group were remarkably lower than that in the mask group, but there was no considerable difference in in-hospital mortality. In conclusion, in contrast to mask, hood NIV can reduce the rate of endotracheal intubation and the occurrence of related complications in patients with ARF, which are considerable advantages. However, in view of the shortcomings of this study, a multi-center large sample study is needed to make the research results more accurate and reliable.

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Footnote

Reporting Checklist: The authors have completed the PRISMA reporting checklist. Available at https://dx.doi.org/10.21037/apm-21-2709

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://dx.doi.org/10.21037/apm-21-2709). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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