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ORIGINAL ARTICLE

Controlled ventilation or spontaneous respiration in anesthesia for tracheobronchial foreign body removal: a meta-analysis

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Summary

Background: Either controlled ventilation or spontaneous respiration is commonly used in general anesthesia for inhaled foreign body removal via rigid bronchoscopy. Controversy in the literature exists concerning which form of ventilation is optimally suited for bronchoscopy. We performed a meta-analysis to compare controlled ventilation and spontaneous respiration with respect to complications, operation time, and anesthesia recovery time.
Methods: We searched MEDLINE (1946–2013) and the Cochrane Central Register of Controlled Trials, EMBASE. The articles were evaluated for validity, and the data on complications, including desaturation, laryngospasm, laryngeal edema, bucking and coughing, body movement, breath holding, operation time, and anesthesia recovery time, were extracted by the authors and summarized using odds ratios, mean differences, and 95% confidence intervals (CIs).
Results: From the included studies, 423 subjects received controlled ventilation, whereas 441 subjects received spontaneous respiration. There was no significant difference in the incidence of desaturation between controlled ventilation and spontaneous respiration (odds ratio, 0.70; 95% CI, 0.30–1.63). However, the incidence of laryngospasm was lower when controlled ventilation was performed (OR, 0.27; 95% CI, 0.10–0.76). The operation time (mean difference, −9.07 min; 95% CI, −14.03 to −4.12) was shorter in the controlled ventilation group.
Conclusions: Current evidence does not show a preference for either controlled ventilation or spontaneous respiration, although laryngospasm has a lower incidence when controlled ventilation is performed. Additional clinical studies are required to substantiate this issue.

Introduction

Foreign body inhalation, which is a life-threatening accidental event, occurs most frequently in children between the ages of 1 and 3 (1,2). The gold standard for managing foreign body aspiration is the removal using rigid bronchoscopy (3). During FB removal, sharing the airway with operators and dealing with a potentially affected airway pose a significant challenge for anesthetists. Asphyxiation due to an impacted obstructing aryngeal foreign body carries a 45% mortality rate (4). To ensure oxygenation, the anesthetists have the primary tasks of avoiding airway complications, such as laryngospasm, and facilitating surgery with a stable operating area. However, little evidence is available for guiding anesthetic management for foreign body removal using bronchoscopy (3,5). Three primary ventilatory modes are used during this procedure: spontaneous respiration using either inhaled (6,7) or total intravenous anesthesia (7,8), controlled ventilation through the sidearm of the bronchoscope (9,10), and jet ventilation through a thin catheter (11). The advantages of spontaneous respiration include the following: First, spontaneous respiration carries a lower risk of causing complete airway obstruction without using a muscle relaxant; second, spontaneous respiration can provide continuous ventilation despite interruptions in the anesthesia breathing circuit (12). However, it is difficult to maintain an adequate depth of anesthesia to suppress the airway reflex and simultaneously to maintain adequate ventilatory function and hemodynamic stability during the procedure (13). The arguments in favor of controlled ventilation include an immobilized airway using a muscle relaxant to facilitate the extraction of a tracheobronchial foreign body (14) and over-ventilation to ensure oxygen supply in an immobilized open airway (12). Furthermore, it would be easier to maintain an adequate anesthetic level using a muscle relaxant (15). However, controlled ventilation involves a risk of ball-valve hyperinflation and makes it more difficult to remove the FB (5,16) and a risk of potentially rupturing the lung distal to the obstruction (17). The choice is often based on the institution's protocol and the anesthetist's training. It is not clear whether the ventilatory mode is a relatively insignificant factor in the procedure's outcome.

The aim of this meta-analysis was to identify whether the current evidence supports significant differences between spontaneous respiration and controlled ventilation with respect to complications during bronchoscopy for foreign body removal and the duration of operation and anesthesia recovery period.

Method

Search strategy

A systematic search was conducted by two of the authors (Yuqi Liu and Shitong Li) using the Central Register of Controlled Trials in the Cochrane Library (until December 2013), MEDLINE (1946–2013), and EMBASE (1974–2013). The search strategy was a combination of free text words that included 'foreign body/bodies' AND 'an(a)esthesia' AND 'ventilation/respiration' AND 'bronchoscopy'. The search was not limited to publications in English. The discrepancies were resolved by reexamining the original articles or consulting a third author (Lianhua Chen). The reference lists of all of the relevant articles generated by the above searches were hand-searched for additional studies.

Inclusion and exclusion criteria

Two authors (Yuqi Liu and Shitong Li) independently read the titles and abstracts of the retrieved articles and excluded irrelevant studies. All of the clinical trials that focused on anesthetic techniques and different ventilatory modes for tracheobronchial foreign body removal in subjects under the age of 18 were included. If the ventilatory mode was not mentioned, or if all of the participants received the same anesthesia protocol or the same ventilatory mode, then it was excluded.

Data extraction and assessment

A data collection sheet was used to collect the following data from each study (Table 1): authors, year of publication, ventilatory mode, induction and maintenance of anesthesia, use of muscle relaxants, and outcome measures.

Definition of relevant outcome data

The primary outcome was desaturation, which was defined as an SpO_2 level < 90%. We analyzed each study to determine the occurrence of laryngospasm, laryngeal edema, bucking and coughing, the duration of the operation time (the time from the insertion of the laryngoscope to the complete removal of foreign bodies), and the anesthesia recovery period (the time from the withdrawal of laryngoscope after the removal of foreign bodies to the time of regaining consciousness, orientation of time and place, and following commands).

Statistical analysis

The odds ratio (OR), mean difference, and corresponding 95% confidence interval (CI) were calculated, for dichotomous and continuous outcome data using a fixed-effect model. Statistical heterogeneity was assessed with the I^2 test and assumed to have significant heterogeneity if the I^2 value > 50% was observed. If significant heterogeneity was detected, a random-effects model was used. A p value ≤ 0.05 was considered to be statistically significant. All of the outcome data were analyzed using Review Manager (RevMan, version 5.1; The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark, 2011).

Results

Description of included and excluded studies

The systematic search identified 308 relevant articles. Of the 320 articles, 21 articles met the inclusion criteria after screening the titles and abstracts. Eventually, five controlled trials were included in the meta-analysis (Figure 1) (13,18–21). Among the 16 excluded studies, one study (3) was excluded because it lacked relevant data, and the other 15 studies did not compare different ventilatory modes. The methodological quality of the included studies is summarized in the

Table 1 Characteristics of the studies included in the meta-analysis

Outcome	Desaturation Laryngospasm Intraoperative coughing and Postoperative laryngeal edema	Hypoxemia Laryngospasm Body movement during operation Breath holding Duration of operation Duration of emergence from Anesthesia Intraoperative Postoperative	SpO_2 below 90% Laryngospasm and Choke Slight laryngeal Edema Surgical time Anesthetic induction time Anesthetic recovery time	SpO_2 below 90% Laryngospasm Breath holding Choke Duration of operation Duration of emergence from Anesthesia	Hypoxemia Laryngospasm Body movement Breath holding Pneumothorax Duration of operation Duration of emergence from anesthesia
Anesthesia maintenance	CV: 0.5% halothane + intermittent dose of suxamethonium SV: 1.5–3% halothane	CV: 1–2 mg·kg^{-1} Propofol and 2 mg·kg^{-1} succinylcholine SV: 1–2 mg·kg^{-1} Propofol	CV: Propofol 2–5 mg per (kg·h^{-1}) , remifentanil 0.1–0.3 lg per (kg min) SV: Propofol at 2–5 mg·kg^{-1}·h^{-1} remifentanil 0.05–0.1 g·kg^{-1}·h^{-1}	Not mentioned	CV: propofol (100–150 μg·kg^{-1}·min^{-1}) and remifentanil (0.1 μg·kg^{-1}·min^{-1}) bolus doses of succinylcholine (1 mg·kg^{-1}) as clinically indicated TIVA For SV: Propofol (100–150 μg·kg^{-1}·min^{-1}) and remifentanil (0.1 μg·kg^{-1}·min^{-1}) Inhalation for SV: 3–4% sevoflurane and 4 l·min^{-1} oxygen flow
Ventilation	CV: Intermittent positive pressure ventilation SV: SV through respiratory circuit connected to the side arm of bronchoscope	CV: Manual intermittent positive pressure ventilation SV: Pure oxygen was delivered at a flow rate of 8 l·min^{-1} by connecting the respiratory circuit to the side arm of the bronchoscope	CV: CV by anesthetic machine through endotracheal tube. Temporary extubation and endotracheal tube placed in the hypopharynx close to the glottis with oxygen rate of 6 l·min^{-1} SV: SV though An oxygen tube 6 l·min^{-1} through the lateral hole laryngoscope	CV: Manual intermittent positive pressure ventilation SV: SV through respiratory circuit connected to the side arm of bronchoscope	CV: Manual intermittent positive pressure ventilation SV: SV through the respiratory circuit connected to the side port of the bronchoscope
Anesthesia induction	Either sleep dose of thiopentone or halothane inhalation by mask (participants were not divided in to CV and SV groups until anesthesia induction was finished)	CV: Propofol (4–5 mg·kg^{-1}), fentanyl (1−2 μg·kg^{-1}) and succinylcholine (2 mg·kg^{-1}) SV: Propofol (2 mg·kg^{-1}) and ghydroxybutyrate sodium (70 mg·kg^{-1})	CV: Propofol 1.5 mg·kg^{-1} and fentanyl 2 μg·kg^{-1} Vecuronium bromide 0.1 mg·kg^{-1} SV: 2 μg·kg^{-1} fentanyl 1.5 mg·kg^{-1} Propofol	CV: Propofol 2 mg·kg^{-1}, fentanyl 3–4 μg·kg^{-1} and vecuronium 0.1 m·kg^{-1} SV: Propofol 2 mg·kg^{-1}, ketamine 2 mg·kg^{-1} and fentanyl 1–1.5 μg·kg^{-1}	CV: Propofol (3–5 mg·kg^{-1}), remifentanil (1 mcg·kg^{-1}), and succinylcholine (2 mg·kg^{-1}) SV: TIVA: Propofol (100–150 mg·kg^{-1}·min^{-1}) and remifentanil (0.1 μg·kg^{-1}·min^{-1}) Inhalation: 8% sevoflurane carried by 8 l·min^{-1} oxygen flow
Premedication	Atropine 0.01 mg·kg^{-1}; vocal cords were sprayed with one puff (10 mg) of lidocain 10% spray	Atropine (0.01 mg·kg^{-1}) and methylprednisolone (2 mg·kg^{-1})	0.015 mg·kg^{-1} scopolamine and 2 mg·kg^{-1} phenobarbital 5–8 mg·kg^{-1} ketamine	Scopolamine 0.01 mg·kg^{-1}	Atropine (0.01 mg·kg^{-1}) and corticosteroids

Table 1 Continued

Study groups (*n*)	Intravenous anesthesia CV (17); Inhalation spontaneous ventilation (19)	Intravenous anesthesia CV (120); Intravenous anesthesia with spontaneous respiration (120)	Intravenous anesthesia and endotracheal intubation with muscle relaxation (56); Intravenous anesthesia with spontaneous respiration (36)	Intravenous anesthesia CV (114); Intravenous anesthesia with spontaneous respiration (126)	Intravenous anesthesia CV (104); Intravenous anesthesia and inhalation anesthesia spontaneous ventilation (82 + 70)
Study type	Prospective randomized control study	Prospective randomized control study	Prospective study	Prospective randomized control study	Prospective study
First author, year of publication	Soodan, 2004 (13)	Li, 2010 (18)	Wen, 2012 (21)	She, 2010 (20)	Chen, 2009 (19)

risk-of-bias table (Table 2). Of the five included trials, 423 subjects received controlled ventilation, whereas spontaneous respiration was maintained in 441 subjects. The study characteristics are shown in Table 1. In one article (19), patients received spontaneous respiration were divided into two subgroups: a total intravenous anesthesia subgroup and an inhalation anesthesia subgroup. We combined the two subgroups into the spontaneous respiration group. The controlled ventilation group was also divided into two subgroups in that article: a manual intermittent positive pressure ventilation subgroup and a manual jet ventilation subgroup. Although a muscle relaxant was used in both subgroups, we did not combine the two subgroups because the methods for providing oxygen are different and the combination would increase heterogeneity. In another study (18), the jet ventilation group was not included.

Intraoperative desaturation

All of the five studies reported the incidence of intraoperative desaturation. Of the five studies, only Soodan *et al.* (13) focused on the severity of desaturation and reported the number of desaturation episodes per patient in each group; however, we could not determine the incidence of desaturation from their data. Therefore, the other four studies (18–21) that enrolled 708 patients were included in the meta-analysis. Two studies (18,19) reported a significant decrease in the incidence of desaturation; however, the pooled results did not reveal a significant difference in the incidence of desaturation (odds ratio, 0.70; 95% CI, 0.30–1.63) (Figure 2).

Laryngospasm

Laryngospasm was investigated in all five studies (13,18–21). The incidence of laryngospasm was lower when controlled ventilation was performed (odds ratio, 0.27; 95% CI, 0.10–0.76) (Figure 3).

Other complications

Laryngeal edema, bucking and coughing, body movement, and breath holding were reported in two studies (Table 3). The incidence of bucking and coughing (odds ratio, 0.08; 95% CI, 0.03–0.26) and body movement (odds ratio, 0.07; 95% CI, 0.01–0.59) was significantly decreased in the controlled ventilation group. Pooled results did not reveal a significant difference in the incidence of laryngeal edema (odds ratio, 0.36; 95% CI, 0.01–10.76) or breath holding (odds ratio, 0.18; 95% CI, 0.003–1.17).

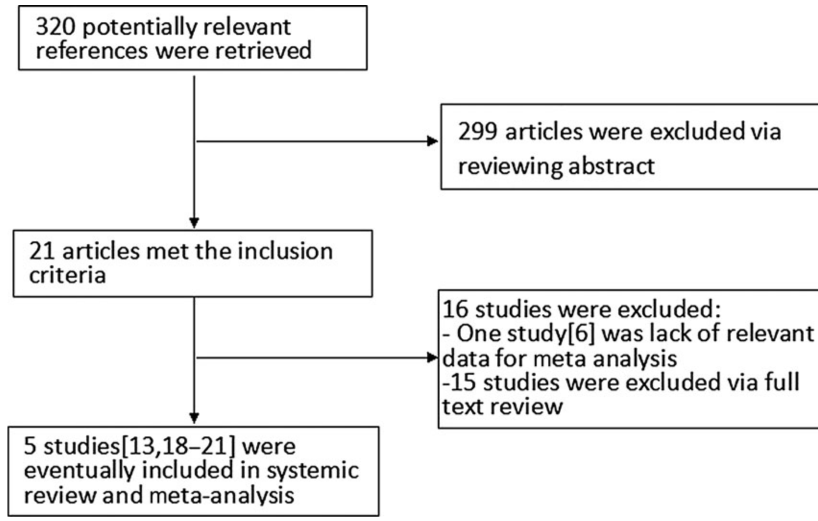

Figure 1 Flow diagram of included and excluded studies.

Table 2 Risk of bias

Included studies	Adequate sequence generation	Allocation concealment	Blinding	Incomplete data addressed	Free of selective reporting
Soodan, 2004 (13)	Yes	No	No	Yes	Yes
Wen, 2012 (21)	No	No	No	Yes	Yes
Li, 2010 (18)	Yes	No	Yes	Yes	Yes
She, 2010 (20)	Yes	No	No	Yes	Yes
Chen, 2009 (19)	No	No	No	Yes	Yes

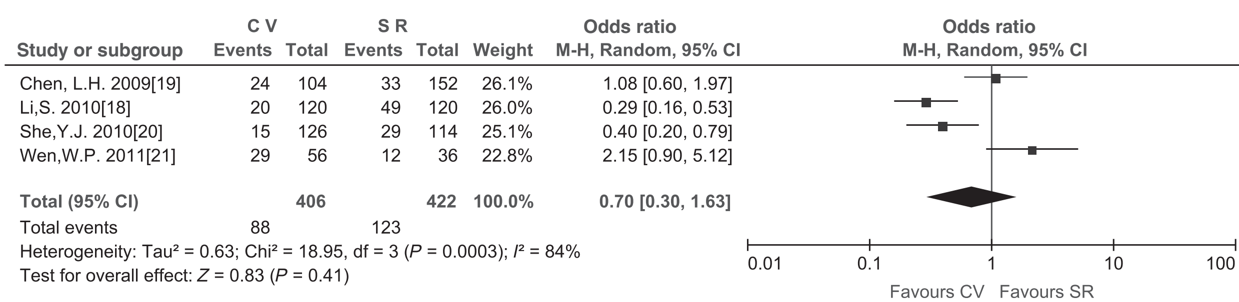

Figure 2 Forest plot for desaturation during foreign body removal. CV, control ventilation; SR, spontaneous respiration.

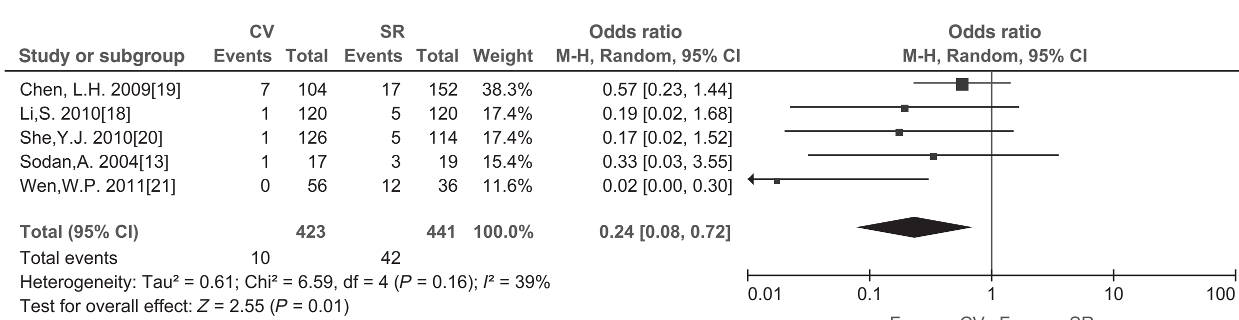

Figure 3 Forest plot for laryngospasm during foreign body removal. CV, control ventilation; SR, spontaneous respiration.

Table 3 Complications reported in two studies

Outcome	Studies	Number of events/ total in control ventilation group	Number of events/ total in spontaneous ventilation group	Odds ratio (95% confidence interval)
Laryngeal edema	Soodan, (13) Wen, (21)	5/73	9/55	0.36 (0.01, 10.76)
Bucking and coughing	Soodan, (13) She, (20)	3/143	35/133	0.08 (0.03, 0.26)
Body movement	Chen, (19) Li, (18)	10/244	100/272	0.07 (0.01, 0.59)
Breath holding	Chen, (19) Li, (18)	6/224	31/272	0.18 (0.003, 1.17)

Operation time and anesthesia recovery time

Four studies (18–21) investigated the operation time and anesthesia recovery time. The operation time was shorter in controlled ventilation group than that in spontaneous respiration group (mean difference, −9.07 min; 95% CI, 14.03–4.12) (Figure 4). The anesthesia recovery time was not statistically significantly different between groups (mean different, −11.8 min; 95% CI, −22.39 to 0.02) (Figure 5).

Additional outcomes

Restlessness (13), anesthesia induction time (21), and bronchospasm (21) were investigated in individual study, respectively. There were no significant differences between the two ventilatory modes in these variables.

Discussion

Desaturation is one of the most common complications that occurs during tracheobronchial foreign body removal. Without prompt treatment, desaturation could lead to a life-threatening outcome. Eren *et al.* (22) reported 10 deaths in 1068 children: Seven of the 10 deaths were attributed to hypoxic cardiac arrest. The majority of the studies on tracheobronchial foreign body removal used only one anesthesia technique, either spontaneous respiration (7,8,23) or controlled ventilation with muscle relaxants (9,10), and optimistic results were reported. Our meta-analysis demonstrated that neither spontaneous respiration nor controlled ventilation contributed to the incidence of desaturation. However, we noticed that heterogeneity existed among these trials. Only two studies were prospective, randomized designed

Study or subgroup	CV Mean	CV SD	CV Total	SR Mean	SR SD	SR Total	Weight	Mean difference IV, Random, 95% CI
Chen, L.H. 2009[19]	14	9	104	15	7.5	152	25.9%	−1.00 [−3.10, 1.10]
Li,S. 2010[18]	18.7	2.1	120	29.1	6.2	120	26.8%	−10.40 [−11.57, −9.23]
She,Y.J. 2010[20]	11	6	126	21	9	114	26.1%	−10.00 [−11.96, −8.04]
Wen,W.P. 2011[21]	7.7	4.74	56	23.79	14.82	36	21.3%	−16.09 [−21.09, −11.09]
Total (95% CI)			**406**			**422**	**100.0%**	**−9.07 [−14.03, −4.12]**

Heterogeneity: Tau² = 23.55; Chi² = 69.74, df = 3 (*P* < 0.00001); *I*² = 96%
Test for overall effect: *Z* = 3.59 (*P* = 0.0003)

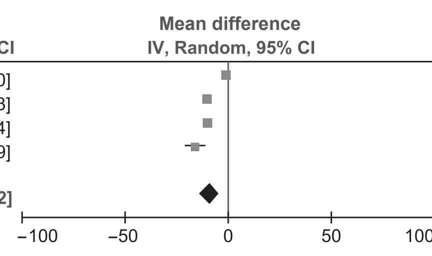

Figure 4 Forest plot for operation time for foreign body removal. CV, control ventilation; SR, spontaneous respiration.

Study or subgroup	CV Mean	CV SD	CV Total	SR Mean	SR SD	SR Total	Weight	Mean difference IV, Random, 95% CI
Chen, L.H. 2009[19]	9	5	104	12.31	7.04	152	25.2%	−3.31 [−4.79, −1.83]
Li,S. 2010[18]	12.1	2.4	120	32.7	6.8	120	25.2%	−20.60 [−21.89, −19.31]
She,Y.J. 2010[20]	28	11	126	49	16	114	24.7%	−21.00 [−24.51, −17.49]
Wen,W.P. 2011[21]	25.68	6.58	56	25.6	5.54	36	25.0%	0.08 [−2.42, 2.58]
Total (95% CI)			**406**			**422**	**100.0%**	**−11.18 [−22.39, 0.02]**

Heterogeneity: Tau² = 129.33; Chi² = 419.02, df = 3 (*P* < 0.00001); *I*² = 99%
Test for overall effect: *Z* = 1.96 (*P* = 0.05)

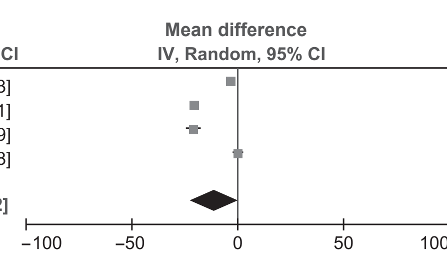

Figure 5 Forest plot for anesthesia recovery time during foreign body removal. CV, control ventilation; SR, spontaneous respiration.

(18,20). Additionally, several details of these trials should be considered. First, propofol and gamma-hydroxybutyrate sodium (18) or ketamine (20) were used to maintain spontaneous respiration, whereas propofol and remifentanil were used in the other three studies. Second, the doses of agents may influence the results. The increased incidence of desaturation observed in the group with total intravenous anesthesia and spontaneous respiration (19) may be attributed to the low doses of anesthetic agents rather than the ventilatory mode (24,25).

Laryngospasm is a common complication that reportedly occurs in approximately 10% of patients with upper airway surgery (26). The incidence of laryngospasm was 10.6% in all of the five studies combined. As our study has inferred, the controlled ventilation group had a lower incidence of laryngospasm. Although the muscle relaxant can release laryngospasm, it does not explain this result. In the spontaneous respiration group, it might be not easy to reach a suitable sedation level that can prevent a harmful reflex, such as laryngospasm or body movement or bucking, and simultaneously maintain spontaneous respiration (3,13). Moreover, laryngospasm is largely related to the depth of anesthesia and pharmacological management. For example, compared with propofol, the incidence of laryngospasm is higher in children anesthetized with sevoflurane (27). Of the five studies included in the analysis, two studies (13,19) used volatile agents and one study used a volatile agent only in spontaneous respiration group. That would also increase heterogeneity.

Laryngeal edema, bucking and coughing, body movement, and breath holding during operation are indicated in only two studies. No difference was found in laryngeal edema and breath holding, although the controlled ventilation group had a lower incidence of bucking and coughing and body movement, which could be easily explained by the use of a muscle relaxant.

Compared with controlled ventilation, the operation time was significantly increased when spontaneous respiration was maintained. First, as discussed previously, it is difficult to maintain spontaneous respiration. Body movement or bucking and coughing could disturb the operator. Second, spontaneous respiration was usually chosen in cases where the foreign body was perceived to be difficult to remove (21).

Although two of the randomized control studies (18,20) concluded that the anesthesia recovery time was increased in the spontaneous respiration group, the meta-analysis did not show a significant difference. The explanation is attributed to a difference in anesthesia protocols. The anesthesia level is usually hard to titrate at the end of the procedure because of the sudden termination of the bronchoscopy as soon as the foreign body is removed (10). Therefore, careful observation and treatment during the recovery period are critical to avoid airway-related complications that may occur during the period immediately after bronchoscopy.

Jet ventilation has been reported for foreign body removal (28), although this method is not yet widely adopted or just been an assisted technique (11). Jet ventilation is perceived to more likely cause barotrauma or dislodgment of the foreign body. Of the five studies evaluated, two studies (18,19) compared manual jet ventilation with spontaneous and controlled ventilation and concluded that manual jet ventilation is a safe and effective technique. To avoid barotrauma, the key point is to maintain an easy outflow of air/oxygen outflow (29). In the case of trachea-bronchial mucosa damage, it is also not suitable to use either jet ventilation or controlled ventilation (30).

This meta-analysis has several limitations. First, among the five studies included, only three (13,18,20) were prospective, randomized, controlled studies and the others (19,21) were nonrandomized controlled studies and the ventilatory mode was chosen depending on the anesthetist's preference, which may have induced a bias. Second, the five studies were subject to clinical heterogeneity, with respect to premedication before surgery, anesthesia induction, anesthesia maintenance, and other factors. The spontaneous respiration was maintained by either total intravenous anesthesia or inhalation. Third, in two studies that used jet ventilation (18,19), the authors compared three ventilatory modes for foreign body removal. We extracted a portion of the data, although jet ventilation was also controlled because a muscle relaxant was administered and the airway was controlled. Combining these two modes is not suitable because the ventilation was performed differently, one through the bronchoscope and the other through an individual catheter. Finally, the lack of data concerning a patients' basic status, such as degrees of respiratory distress, oxygen requirement, and estimate of the time from the aspiration event, might cause a bias when the data were pooled. All of these enrolled studies had a lack of postprocedure condition: We thought that would be useful to evaluate whether different ventilation mode leads to different results for the inhaled patients. Altogether, there are too few trials and patients and insufficient events with respect to adverse outcomes; the calculated pooled odds ratios or mean differences should be interpreted with caution. Larger prospective studies, using both inhaled and intravenous maintenance of anesthesia, are warranted to further evaluate whether spontaneous respiration or controlled ventilation is more advantageous.

Conclusions

The current evidence suggested that there was no significant difference in the complications including desaturation between spontaneous respiration and controlled ventilation, except laryngospasm, which was decreased when controlled ventilation was performed. Furthermore, a shorter operation time was noted in controlled ventilation. However, no strong evidence indicated that one technique was superior. Because of the heterogeneity of the included studies, additional clinical studies on this issue are required and as well as consequential updating of this meta-analysis.

Funding

None.

Conflict of interests

No conflicts of interest declared.

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