Title

Anesthesia during rigid bronchoscopy for tracheobronchial foreign body removal in children：A Systematic Review and Meta-analysis of Comparative Studies

Running title

Anesthesia during rigid bronchoscopy for tracheobronchial foreign body removal in children

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Conflicts of interest

None.

Article type

Controversy continues regarding the anesthetic management for children on tracheal foreign body removal. We concluded that sevoflurane-based volatile anesthesia causes fewer perioperative complications and shorter operation time compared with propofol-based total intravenous anesthesia.

Abstract

Background: There is no consensus regarding the optimal anesthetic approach to rigid bronchoscopy in children suffering from tracheobronchial FBA. We performed this meta-analysis to assess the efficacy and safety of the different anesthesia agents and ventilation modes for tracheobronchial foreign body removal via rigid bronchoscopy in young children.

Methods: A systematic search of three major databases for all relevant articles. A meta-analysis was performed to analyze the data.

Results: Four trials for evaluating different anesthetics and six trials for evaluating two kinds of ventilation modes were found. Compared with the sevoflurane-based volatile anesthesia group (Group Sevo) , the rate of perioperative complications included hypoxemia (OR, 2.07; 95% CI, 1.38–3.11; P=0.0004; I^2 = 0%), apnea (OR, 2.74; 95% CI, 1.11–6.78; P = 0.03; I^2 = 60%), laryngospasm (OR, 2.89; 95% CI, 1.67–4.98; P=0.0001; I^2 = 0%), cough/bucking (OR, 2.93; 95% CI, 1.86–4.63; P<0.00001; I^2 = 0%), and body movement (OR, 3.51; 95% CI, 2.03–6.09; P<0.00001; I^2 = 0%) were significantly increased in the propofol-based total intravenous anesthesia (Group Prop) and the duration of operation (mean difference, 1.09min; 95% CI, 0.46–1.73; P=0.0007, I^2 =16%) were longer in the Group Prop. Compared with the control ventilation group (Group CV), the incidences of laryngospasm (OR, 0.16; 95% CI, 0.05–0.56; P=0.004; I^2 = 54%), apnea (OR, 0.21; 95% CI, 0.09–0.50;

P=0.0004; I^2 = 0%), arrhythmia (OR, 0.19; 95% CI, 0.06–0.60; P=0.005; I^2 = 45%) and cough/bucking (OR, 0.03; 95% CI, 0.01–0.10; P<0.00001; I^2 = 41%) increased in the spontaneous ventilation group (Group SV) and the duration of operation (mean difference,-8.77min; 95% CI, -13.64–-3.91; P=0.0004, I^2 = 95%)and emergence from anesthesia (mean difference, -11.5min; 95% CI, -22.57–-0.43, P=0.04; I^2 = 99%) significantly prolonged in the Group SV.

Conclusions: Our meta-analysis suggests that sevoflurane-based volatile anesthesia was superior to propofol-based total intravenous anesthesia for the management of foreign body aspiration in children. There is still no strong evidence indicated that one ventilation technique was superior. Additional clinical studies on this issue and consequential updating of this meta-analysis are required.

Keywords

anaesthesia, rigid bronchoscopy, foreign bodies, Meta-analysis, Child

1. Introduction

Foreign-body aspiration（FBA） continues to pose a significant healthcare concern in the pediatric population accounting for the high morbidity as well as the nonnegligible incidence of anoxic brain injury and death (2.2% and 1.8%, respectively)[1]. Though the use of computerized tomography virtual bronchoscopy and flexible bronchoscopy are increasing and they both have been demonstrated safe and cost-saving in children with suspected FB aspiration [2-4], rigid bronchoscopy is still the standard diagnostic and therapeutic procedure with distinct advantage of providing ongoing ventilation and excellent visualization [5-6]. The role of the anesthesiologist becomes more challenging to maintain airway and hemodynamic stability as the potentially obstructed airway is shared with the surgeon and the pediatric patient is not cooperative [7-8].

The use of general anesthesia was commonly recommended for foreign body extraction [9]. But it sustains an ongoing controversial discussion on which technique should be used, especially focusing on possible complications and mortality. In children, sevoflurane is commonly used in many hospitals for mask induction and maintenance of anesthesia when rigid bronchoscopy is performed. The rationale for the choice of sevoflurane-based volatile anesthesia is that it has no irritation to the respiratory passage and is used frequently in pediatric surgery [10]. Propofol provides rapid and smooth induction of anesthesia and exhibits rapid clearance from the body [11]. Some anesthesiologists recommend the use of propofol-remifentanil for anesthesia with spontaneous ventilation for pediatric surgery based on their pharmacological

properties and synergic effect [12]. Nevertheless, it was reported that perioperative complications occurred more frequently in children anesthetized with propofol [13].

In addition, maintaining proper ventilation and control of the airway is essential during interventional rigid bronchoscopy. Spontaneous ventilation reduces risk of foreign-body dislodgment/ movement and has better V/Q matching, less air trapping was advocated before the mid-1990s [2] [14], whereas more recently, reports that in favor of controlled ventilation were increasing accounting for decreasing risk of reflex activation of the airway [15] [16]. For clinicians, choosing whether to maintain spontaneous ventilation or controlled ventilation is a difficult decision because both methods have advantages and disadvantages.

Herein, to facilitate clinical decisions for anesthetic management during rigid bronchoscopy in children, we performed the current study to evaluate the efficacy and safety of different anesthesia and ventilation modes by systemically searched and meta-analyzed the available literature.

2. Methods

This study was registered with PROSPERO (CRD42020171261), describing in advance the aims and methods. The study was performed under the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) [17]and the Cochrane Handbook [18].

2.1 Literature-search strategy

The systematic literature search of databases was conducted on 21 December 2019 without restriction to regions, publication types, or languages. The primary sources were the electronic databases of PubMed (1987-2019), Cochrane Library (2004-2017) and Embase (1988-2019). Databases were searched for the following key terms, found mainly in titles, keywords, and abstracts: (rigid bronchoscop*) AND (foreign bod*) AND (anesthesia[MeSH] OR anaesthetic OR anaesthesia OR analgesia OR sedation) AND (paediatric [MeSH] OR children OR child OR kids OR childhood OR ped OR newborn OR infant OR premature*). The reference lists of all retrieved studies and review articles were manual-searched to broaden the search.

2.2 Inclusion and exclusion criteria

All the patients in the articles were candidates for rigid bronchoscopy under general anesthesia due to foreign body aspiration and under the age of 18 years old. All available randomized controlled trials (RCTs) and prospective/retrospective comparative studies that compared inhalation with intravenous anesthesia, or spontaneous with control ventilation were included. Review, case reports, and adult studies were excluded.

2.3 Data collection and outcomes of interest

The following data from included articles were extracted and summarized: first author; year of publication; study type; age scope; ASA physical status; study groups; premedication; anesthesia induction; anesthesia maintenance; ventilation mode; outcomes.

The primary outcomes were the rate of perioperative complication which include hypoxemia, apnea, laryngospasm, cough/bucking, body movement, arrhythmia, laryngeal edema, and bronchospasm. Hypoxemia is the most common adverse event in rigid bronchoscopy for FB removal and was defined as SpO_2 (oxygen saturation) < 90%. The secondary outcomes we analyzed were operative time (the period from the insertion of the rigid bronchoscope to the withdrawal of bronchoscope after complete removal of foreign bodies) and duration of emergence from anesthesia (the period from discontinuation of anesthetic agents to the patient regained consciousness, the orientation of time and place, and to follow commands).

2.4 Quality assessment and statistical analysis

We used the Cochrane risk of bias tool to evaluate the methodological quality of RCTs which includes seven aspects: sequence generation; allocation sequence concealment; the blinding of patients or health care providers; the blinding of outcome assessors; incomplete outcome data; selective outcome reporting and other bias. The risk of bias was classified as follows: “low”, “high”, or “unclear”. A trial was considered as having a high risk of bias if one or more risks of bias were classified unclear or high [18]. The modified Newcastle-Ottawa scale (NOS) was used

to assess the methodological quality of non-randomized controlled trials, which consists of three factors: patient selection, comparability of the study groups, and assessment of outcome. The risk of bias was classified by a score of 0–9, with achieving six or more scores were deemed to be high-quality [19].

We used Review Manager 5.3 (Cochrane Collaboration, Oxford, UK) to analyze the outcome data. The odds ratio (OR) and weighted mean difference (WMD) were used to compare dichotomous and continuous variables, respectively. All results were reported with 95% confidence intervals (CIs). We considered there was a statistical difference if a P-value ≤ 0.05. Statistical heterogeneity between those studies was quantified using both the chi-squared test (with $p \leq 0.10$ indicated substantial heterogeneity) and the I^2 index statistic (with $I^2 \geq 50\%$ indicated substantial heterogeneity). The fixed-effects model was used if there was no substantial heterogeneity between studies; otherwise, the random-effects model was used. A forest plot was used to summarize the results of the meta-analysis. We could not use the funnel plot to judge the publication bias because the included articles in each of the two analyses were limited.

3. Results

3.1 Description of included and excluded studies

The initial systematic search of the databases yielded 256 potential articles (Fig. 1). An additional record had been cited as references. After elimination of 94 duplicate records, 163 titles and abstracts were screened. 132 articles were excluded as irrelevant topics, reviews, clinical trial registration, case reports, and 31 manuscripts remained for full-text screening. After comprehensively screening the full texts, one study was excluded for not contain relevant data, 13 publications were not comparative studies, and 8 studies did not compare the desired anesthetic technique. Eventually, 9 publications including a total of 1434 cases were considered to fulfill the predefined eligibility criteria and were included in the final systematic review.

The characteristics of the included studies are shown in Table.1. Among the eligible studies, there were six RCTs, two prospective nonrandomized observational studies and one retrospective study. We considered the risk of bias of the included RCTs was generally high (Fig. 2). Two eligible non-randomized controlled trials were deemed to be high-quality, while one was low-quality.

Of the nine included trials, six and four were included to compare controlled ventilation and spontaneous ventilation, sevoflurane-based volatile anesthesia and propofol-based total intravenous anesthesia with spontaneous ventilation, respectively. One trial has tried to explore appropriate anesthetic techniques used for removal of the tracheobronchial foreign body via self-retaining laryngoscopy and Hopkins telescopy in children compared with rigid bronchoscopy [20]. So in this

article, the self-retaining laryngoscopy and Hopkins telescopy group was not included. In another two studies [13] [21], the method for providing oxygen via jet ventilation was different when compared with that via manual intermittent positive pressure ventilation (IPPV). So jet ventilation group was not taken into account to avoid increasing heterogeneity.

3.2 Comparison of propofol-based total intravenous anesthesia and sevoflurane-based volatile anesthesia

Four trials evaluated the comparison of propofol-based total intravenous anesthesia and sevoflurane-based volatile anesthesia with spontaneous respiration [13,22-24]. The pooled results are shown in Fig. 3. The incidence of apnea was described in all of the four studies and it was lower in the Group Sevo (OR, 2.74; 95% CI, 1.11–6.78; P = 0.03; I^2 = 60%) than that in the Group Prop. The data from two studies showed that the occurrence rate of hypoxemia (OR, 2.07; 95% CI, 1.38–3.11; P=0.0004; I^2 = 0%) was also lower in the Group Sevo. Laryngospasm was reported in three studies. The rate of laryngospasm (OR, 2.89; 95% CI, 1.67–4.98; P=0.0001; I^2 = 0%) was significantly increased in the Group Prop. Three studies reported the rate of intraoperative cough/bucking, it was lower in the Group Sevo (OR, 2.93; 95% CI, 1.86–4.63; P<0.00001; I^2 = 0%). Concerning body movement, the data from two studies indicated that the rate in the Group Prop is significantly increased compared with the Group Sevo (OR, 3.51; 95% CI, 2.03–6.09; P<0.00001; I^2 = 0%).

All of the four studies investigated the operation time and duration of emergence from anesthesia. The duration of operation was shorter in the Group Sevo than that in

the Group Prop (mean difference,1.09min; 95% CI, 0.46–1.73; P<0.0007, I^2 =16%). There was no statistically significant difference between two groups for the duration of emergence from anesthesia (mean difference,3.35min; 95% CI, -0.57–7.26; P =0.09; I^2 = 98%).

3.3 **Comparison of spontaneous ventilation and control ventilation.**

The data of 6 trials were extracted to compare the ventilation models [13,15,16,20,21,25]. The pooled results showed in . All six articles investigated the incidence of laryngospasm, it was higher in the Group SV than that in the Group CV (OR, 0.16; 95% CI, 0.05–0.56; P=0.004; I^2 = 54%). The incidence of hypoxemia during the operation was described in five studies and there was no statistical difference between groups (OR, 0.51; 95% CI, 0.21–1.24; P = 0.14; I^2 = 83%). Apnoea and body movement were investigated in three records. The incidence rate of apnea (OR, 0.21; 95% CI, 0.09–0.50; P=0.0004; I^2 = 0%) and body movement (OR, 0.10; 95% CI, 0.05–0.18; P<0.00001; I^2 = 9%) was significantly increased in the Group CV than that in the Group SV. Cough/bucking was reported in three articles and the rate of intraoperative cough/bucking was lower in the Group CV as compared with that in the Group SV (OR, 0.03; 95% CI, 0.01–0.10; P<0.00001; I^2 = 41%). Three trials showed the rate of arrhythmia and the evidence indicated that the incidence was decreased in the Group CV than that in the Group SV (OR, 0.19; 95% CI,0.06–0.60; P=0.005; I^2 = 45%). And two articles evaluated the occurrence of bronchospasm, pooled results did not reveal a significant difference between two groups (OR, 0.60; 95% CI,0.22–1.67; P=0.33; I^2 = 40%). About laryngeal edema, data from three studies was also too

limited to determine significance (OR, 0.18; 95% CI, 0.01–3.11; P = 0.24; I^2 = 76%).

The operation time and duration of emergence from anesthesia were investigated in four studies. The data indicated the duration of operation (mean difference, -8.77min; 95% CI, -13.64–-3.91; P=0.0004, I^2 = 95%) and emergence from anesthesia (mean difference,-11.5min; 95% CI, -22.57–-0.43, P=0.04; I^2 = 99%) was shorter in the Group CV group than that in the Group SV group.

4. Discussion

Volatile anesthesia and total intravenous anesthesia techniques are widely used in pediatric patients undergoing rigid bronchoscopy with providing satisfactory operating conditions [24]. The use of the two anesthesia techniques varies among anesthesiologists. In this current meta-analysis, we included 716 cases of pediatric patients undergoing rigid bronchoscopy with general anesthesia with spontaneous ventilation to compare anesthesia agents. We found the rate of perioperative adverse events was significantly higher in the Group Prop than that in Group Sevo. Appropriate oxygenation is of prime importance during the anesthetic management for rigid bronchoscopy in children because of higher risk hypoxemia as a result of lower functional reserve capacity and higher oxygen consumption and pneumonia as a result of a chemical reaction when foreign body lodged in the bronchi [13]. Many anesthetists have been working on preventing or improving hypoxemia. Apnea resulting from anesthesia will lead to a gradual SaO_2 decrease, further hypoxia [26]. The pooled results showed the occurrence of hypoxemia and apnea was increased in children who received propofol-based total intravenous anesthesia which was in line with the findings by Chai et al. [23]. This can be explained by that sevoflurane have no irritation to the respiratory passage while propofol can cause a significant respiratory depression [26]. J. Zhang et al. reported that there was a similar incidence of apnea in the two groups within two minutes of insertion of the bronchoscope, this discrepancy may be due to an airway reflex during light anesthesia because of the relatively small doses of general anesthesia [24]. Laryngospasm was the most common adverse event

related to anesthesia and reported that it occurred more frequently in children anesthetized with sevoflurane compared with propofol [27]. Our study inferred that the Group Prop had a higher incidence of laryngospasm. The reason for the higher frequency was unclear and may have been partly due to inadequate depth of anesthesia. Also, our study showed that increased intraoperative cough/bucking and body movement in the Group Prop. This may be due to the muscle relaxing effect by sevoflurane which may subdue the reflex response of the glottis to the stimuli of the tracheobronchial procedure [28]. The duration of operation and emergence from anesthesia had been identified as the risk factors associated with intraoperative or postoperative hypoxemia in rigid bronchoscopy [13]. The operation time was significantly longer when propofol-based total intravenous anesthesia was used. As discussed previously, extra time was needed for frequent adjustment of the depth of anesthesia or management of complications in the Group Prop. There was not a significant difference in the time emergence from anesthesia in two groups. Two of four included studies concluded that the anesthesia recovery time in the sevoflurane volatile anesthesia group was shorter than that in the Group Prop [13,22]. The discrepancy may be due to delayed recovery caused by the combined use of other intravenous anesthetic agents such as opioids remifentanil or propofol. Conclusively, sevoflurane-based volatile anesthesia is superior to propofol-based total intravenous anesthesia. However, the volatile agent may cause environmental pollution in the operating room.

Ventilation mode is one of the key factors causing perioperative complications.

Discussion regarding the optimal method of ventilation (spontaneous or controlled) is still ongoing. Yuqi Liu et al. performed a meta-analysis to compare two kinds of ventilation modes concerning complications, operation time, and anesthesia recovery time [29]. They concluded that laryngospasm has a lower incidence when controlled ventilation is performed. We included six trials, 870 patients to update this meta-analysis in the current study. Our finding was in line with Yuqi Liu et al. respect to operation time and the incidence of laryngospasm, hypoxemia, cough/bucking, body movement, and laryngeal edema. And we also found an increased incidence of apnea and arrhythmia and significantly prolongation of anesthesia recovery time observed in the Group SV that may be attributed to the inadequate depth of anesthesia when spontaneous ventilation was used**.** Lighter anesthesia would make a patient more sensitive and reactive to the presence of the bronchoscope. Deeper anesthesia increases the risk of inhibiting hemodynamic or respiration and delayed recovery. The muscle-relaxant technique can provide an even and sufficient depth of anesthesia for rigid bronchoscopy and decrease anesthetic effects on cardiac output [16,30]. Our meta-analysis showed that neither spontaneous ventilation nor controlled ventilation contributed to the incidence of bronchospasm and no significant difference was found. In general, controlled ventilation techniques provided a good anesthetic status for surgery and gave a further advantage for bronchoscope manipulation because of the muscle relaxation caused by succinylcholine or vecuronium bromide or atracurium. However, there was no strong evidence indicated that controlled ventilation was superior to spontaneous ventilation due to the heterogeneity that might be related to a

difference in anesthesia protocols and uncertainty in the depth of anesthesia.

More recently, dexmedetomidine/propofol-total i.v. anesthesia was reported to offer an ideal condition for rigid bronchoscopy by producing obtunded airway reflexes and stable hemodynamic and respiratory profiles in spontaneously ventilating children compared with remifentanil/propofol- total i.v. anesthesia, but significantly prolonged recovery time [31]. Leyla Teksan et al. conducted a dose study of remifentanil combined with propofol and concluded a remifentanil 0.2 μg/kg/min infusion with propofol provides hemodynamic stability and early recovery [32]. Moreover, manual jet ventilation using Manujet III was increasing and reported that it appears superior to any other ventilation mode for tracheobronchial foreign body removal in children because of producing fewer episodes of intraoperative hypoxemia with providing continuous ventilation [13,21,33]. Based on the results of our study and prior reports, we suggest that future prospective studies may illustrate improved combination medication, dosing protocols for the drugs and ventilation mode to produce an appropriate depth of anesthesia with the least incidence of adverse airway reflexes. Besides, factors associated with severe complications also include the condition of the patient and the experience of the doctor, instruments used. Therefore, close communication between adequately trained professionals with a multidisciplinary team is essential [34].

The present meta-analysis has several limitations. First, only a small number of randomized clinical trials were included and the quality of these enrolled studies was generally low. Second, there is no accurate and consistent method used for assessing

the depth of anesthesia in those included articles. Those limitations might cause a bias when the data were pooled. Finally, future systematic reviews should assess respiratory hemodynamics parameters when enough literature is available. Besides, larger prospective studies, with bigger sample size and proper randomization and controlling for confounding factors, are warranted to further evaluate the anesthetic technique for rigid bronchoscopy in children.

5.Conclusions

Based on the findings of this study, it can be deduced that sevoflurane-based volatile anesthesia causes fewer perioperative complications and shorter operation time for the management of foreign body aspiration in children compared with propofol-based total intravenous anesthesia. Further study for combination medication, dosing protocols for the drugs and delivery system to produce adequate anesthesia are warranted for further evaluation. There was no strong evidence indicated that which ventilation technique was superior because of the heterogeneity of the included studies, additional clinical studies with proper randomization and controlling for confounding factors on this issue and consequential updating of this meta-analysis are required to generate a definitive recommendation.

Ethical approval

There is no need for this.

References:

[1] Kim IA, Shapiro NL, Bhattacharyya NJL. The national cost burden of bronchial foreign body aspiration in children**.** Laryngoscope. 2015;125(5):1221-1224.

[2] Martinot A, Closset M, Marquette CH, et al. Indications for flexible versus rigid bronchoscopy in children with suspected foreign-body aspiration**.** Am J Respir Crit Care Med. 1997;155(5):1676-1679.

[3] Pitiot V, Grall M, Ploin D, Truy E, Ayari Khalfallah S. The use of CT-scan in foreign body aspiration in children: A 6 years' experience**.** Int J Pediatr Otorhinolaryngol. 2017;102:169-173.

[4] Ozkurt H, Bahadir E, Ucgul A, et al. Comparison of multidetector computed tomography-virtual bronchoscopy and conventional bronchoscopy in children with suspected foreign body aspiration**.** Emerg Radiol. 2008.

[5] Borah TJ, Sonowal J, Sailo LT, Nandy SJJoC, Research D. Rigid Bronchoscopy and Jet Ventilation in Foreign Body Aspiration in A Two-Year-Old Female: A Case Report**.** JCDR. 2018.

[6] Tomaske M, Gerber AC, Weiss M. Anesthesia and periinterventional morbidity of rigid bronchoscopy for tracheobronchial foreign body diagnosis and removal**.** Paediatr Anaesth. 2006;16(2):123-129.

[7] Divarci E, Toker B, Dokumcu Z, et al. The multivariate analysis of indications of rigid bronchoscopy in suspected foreign body aspiration**.** Int J Pediatr Otorhinolaryngol. 2017;100:232-237.

[8] Liu J, Xiao K, Lv X. Anesthesia and ventilation for removal of airway foreign

bodies in 35 infants**.** Int J Clin Exp Med. 2014;7(12):5852-5856.

[9]Londino, A. V., 3rd and N. Jagannathan. Anesthesia in Diagnostic and Therapeutic Pediatric Bronchoscopy. Otolaryngologic Clinics of North America. 2019;52(6): 1037-1048.

[10] Johr M, Berger TMJBP, Anaesthesiology RC. Paediatric anaesthesia and inhalation agents**.** Best Practice & Research Clinical Anaesthesiology. 2005;19(3):501-522.

[11] Bryson HM, Fulton BR, Faulds D. Propofol. An update of its use in anaesthesia and conscious sedation**.** Drugs. 1995;50(3):513-559.

[12] Drover DR, Litalien C, Wellis V, Shafer SL, Hammer GB. Determination of the pharmacodynamic interaction of propofol and remifentanil during esophagogastroduodenoscopy in children**.** Anesthesiology. 2004;100(6):1382-1386.

[13] Chen LH, Zhang X, Li SQ, et al. The risk factors for hypoxemia in children younger than 5 years old undergoing rigid bronchoscopy for foreign body removal**.** Anesth Analg. 2009;109(4):1079-1084.

[14] Perrin G, Colt HG, Martin C, et al. Safety of interventional rigid bronchoscopy using intravenous anesthesia and spontaneous assisted ventilation. A prospective study**.** Chest. 1992;102(5):1526-1530.

[15] Mashhadi L, Sabzevari A, Gharavi Fard M, et al. Controlled vs Spontaneous Ventilation for Bronchoscopy in Children with Tracheobronchial Foreign Body**.** Iran J Otorhinolaryngol. 2017;29(95):333-340.

[16] Soodan A, Pawar DK, Subramanium RJPA. Anesthesia for removal of inhaled

foreign bodies in children. Paediatr Anaesth. 2005;14(11):947-952.

[17] Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. Bmj. 2009;339:b2700.

[18] Cumpston M, Li T, Page MJ, et al. Updated guidance for trusted systematic reviews: a new edition of the Cochrane Handbook for Systematic Reviews of Interventions. Cochrane Database Syst Rev. 2019;10:Ed000142.

[19] 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;25(9):603-605.

[20] Wen WP, Su ZZ, Wang ZF, et al. Anesthesia for tracheobronchial foreign bodies removal via self-retaining laryngoscopy and Hopkins telescopy in children. Eur Arch Otorhinolaryngol. 2012;269(3):911-916.

[21] Li S, Liu Y, Tan F, Chen J, Chen L. Efficacy of manual jet ventilation using Manujet III for bronchoscopic airway foreign body removal in children. Int J Pediatr Otorhinolaryngol. 2010;74(12):1401-1404.

[22] Liao R, Li JY, Liu GY. Comparison of sevoflurane volatile induction/maintenance anaesthesia and propofol-remifentanil total intravenous anaesthesia for rigid bronchoscopy under spontaneous breathing for tracheal/bronchial foreign body removal in children. Eur J Anaesthesiol. 2010;27(11):930-934.

[23] Chai J, Wu XY, Han N, Wang LY, Chen WM. A retrospective study of anesthesia during rigid bronchoscopy for airway foreign body removal in children: propofol and

418 sevoflurane with spontaneous ventilation**.** Paediatr Anaesth. 2014;24(10):1031-1036.
419 [24] Zhang J, Wang Y, Li B, Zhang WJA, Care I. Remifentail infusion for paediatric
420 bronchoscopic foreign body removal: comparison of sevoflurane with propofol for
421 anaesthesia supplementation for bronchoscope insertion**.** Anaesthesia and Intensive
422 Care. 2010;38(5):905-910.
423 [25] She YJ TY, Zhang YF. [Two different anesthesia and ventilation for removal of
424 airway foreign bodies in 240 children]**.** Zhonghua Er Bi Yan Hou Tou Jing Wai Ke Za
425 Zhi. 2010;45(7):599-601.
426 [26] Sun M, Yuan R, Liu H, Zhang J, Tu S. The effects of repeated propofol
427 anesthesia on spatial memory and long-term potentiation in infant rats under hypoxic
428 conditions**.** Genes Dis. 2020;7(2):245-252.
429 [27] Oberer C, von Ungern-Sternberg BS, Frei FJ, Erb TO. Respiratory reflex
430 responses of the larynx differ between sevoflurane and propofol in pediatric patients**.**
431 Anesthesiology. 2005;103(6):1142-1148.
432 [28] Lerman JJA, Analgesia. Sevoflurane in pediatric anesthesia**.** A A Pract.
433 1995;81(6).
434 [29] Liu Y, Chen L, Li S. Controlled ventilation or spontaneous respiration in
435 anesthesia for tracheobronchial foreign body removal: a meta-analysis**.** Paediatr
436 Anaesth. 2014;24(10):1023-1030.
437 [30] Kosloske AM. Bronchoscopic extraction of aspirated foreign bodies in children**.**
438 Am J Dis Child. 1982;136(10):924-927.
439 [31] Chen KZ, Ye M, Hu CB, Shen X. Dexmedetomidine vs remifentanil intravenous

anaesthesia and spontaneous ventilation for airway foreign body removal in children. Br J Anaesth. 2014;112(5):892-897.

[32] Teksan L, Baris S, Karakaya D, Dilek A. A dose study of remifentanil in combination with propofol during tracheobronchial foreign body removal in children. J Clin Anesth. 2013;25(3):198-201.

[33] Tian X, Qiang B, Liu Y, Xia R. [Manujet III manual jet ventilation used in tracheobronchial foreign bodies removal in children]. Lin Chung Er Bi Yan Hou Tou Jing Wai Ke Za Zhi. 2013;27(4):187-188, 192.

[34] Burton EM, Brick WG, Hall JD, Riggs W, Houston CSJSMJ. Tracheobronchial foreign body aspiration in children. South Med J. 1996;89(2):195-198.

Figure legends:

Table 1 - Characteristics of the included studies.

Fig. 1- Flow diagram of studies identified, included and excluded.

Fig. 2-The risk of bias of the included RCTs.

Fig. 3-Forest plot for outcomes of comparison for propofol-based total intravenous anesthesia group (Group Prop) and sevoflurane-based volatile anesthesia (Group Sevo); CI, confidence interval; (A) apnea; (B) cough/bucking; (C) hypoxemia; (D) laryngospasm; (E) body movement; (F) duration of operation; (G) duration of emergence from anesthesia.

Fig. 4-Forest plot for outcomes of comparison for spontaneous ventilation group and control ventilation group; CI, confidence interval. (A) cough/bucking; (B) laryngospasm; (C) apnoea; (D) arrhythmia; (E) body movement ; (F) hypoxemia; (G) laryngeal edema; (H) bronchospasm; (I) duration of operation; (J) duration of emergence from anesthesia.

Search strategy：

1. Embase :'rigid bronchoscopy':ti,ab,kw AND 'foreign body':ti,ab,kw AND (anesthesia:ti,ab,kw OR anaesthetic:ti,ab,kw OR anaesthesia:ti,ab,kw OR sedation:ti,ab,kw) AND (paediatric:ti,ab,kw OR children:ti,ab,kw OR child:ti,ab,kw OR kids:ti,ab,kw OR childhood:ti,ab,kw OR ped:ti,ab,kw OR newborn:ti,ab,kw OR infant:ti,ab,kw OR premature*:ti,ab,kw)

2.PubMed: (((rigid bronchoscop*[Title/Abstract]) AND foreign bod*[Title/Abstract]) AND (anesthesia[MeSH] OR anaesthetic OR anaesthesia OR analgesia OR sedation)) AND (paediatric [MeSH] OR children OR child OR kids OR childhood OR ped OR newborn OR infant OR premature*)

3.cochranelibrary : rigid bronchoscop* in Title Abstract Keyword AND anesthesia OR anaesthetic OR anaesthesia OR anesthesia OR analgesia OR sedation in Title Abstract Keyword AND paediatric OR children OR child OR kids OR childhood OR ped OR newborn OR infant OR premature* in Title Abstract Keyword AND foreign bod* OR FB in Title Abstract Keyword - (Word variations have been searched)