Original Article

A Time Series Observation of Chinese Children Undergoing Rigid Bronchoscopy for an Inhaled Foreign Body: 3149 Cases in 1991–2010

Xu Zhang, Wen-Xian Li, Yi-Rong Cai

Department of Anesthesiology, Eye and ENT Hospital, Fudan University, Shanghai 200031, China

Abstract

Background: In China, tracheobronchial foreign body (TFB) aspiration, a major cause of emergency episode and accident death in children, remains a challenge for anesthetic management. Here, we share our experience and discuss the anesthetic consideration and management of patients with TFB aspiration.

Methods: This was a single-institution retrospective study in children with an inhaled foreign body between 1991 and 2010 that focused on the complications following rigid bronchoscopy (RB). Data including the clinical characteristics of patients and TFB, anesthetic method, and postoperative severe complications were analyzed by different periods.

Results: During the 20-year study period, the charts of 3149 patients who underwent RB for suspected inhaled TFB were reviewed. There were 2079 male and 1070 female patients (1.94:1). A nut (84%) was the most commonly inhaled object. The study revealed a 9% ($n = 284$) overall rate of severe postoperative complications related to severe hypoxemia, laryngeal edema, complete laryngospasm, pneumothorax, total segmental atelectasis, and death with incidences of 3.2%, 0.9%, 1.3%, 0.3%, 0.3%, and 0.1%, respectively. The rates of preoperative airway impairment, negative findings of TFB, and adverse postoperative events have been on the rise in the past 5 years.

Conclusions: The survey results confirmed that hypoxemia remains the most common postoperative complication in different periods. Both controlled ventilation and spontaneous ventilation were effective during the RB extraction of the foreign body at our hospital in the modern technique period. An active respiratory symptom was commonly seen in the groups with negative findings.

Key words: Complication; Inhaled Foreign Body; Rigid Bronchoscope

Introduction

Foreign body aspiration in toddlers, which presents a serious issue in developing countries, not only remains a diagnostic and therapeutic conundrum to otolaryngologists, but presents a major hazard to anesthetists, especially during emergencies when confronting the postoperatively compromised airway. Reports have focused on the ventilation mode and anesthesiology delivery route. The most suitable anesthetic technique for adequate ventilation and oxygenation during rigid bronchoscopy (RB) is still under investigation. The aim of this study is to review our 20-year experience (1991–2010) in the airway management and the subsequent outcomes of RB in children with an inhaled tracheobronchial foreign body (TFB).

Access this article online

Quick Response Code:

Website: www.cmj.org

DOI: 10.4103/0366-6999.151104

Methods

Patients and methods

Case distribution

Institutional review board approval from the Eye and ENT (EENT) Hospital of Fudan University (Shanghai, China) was obtained; a total of 3203 charts of children (<12 years of age) with suspected inhaled foreign bodies underwent RB in 1991–2010 (past 2 decades) were reviewed. Exclusion criteria included incomplete data sets (34 cases) and an emergency invasive airway (tracheal intubation or tracheostomy) prior to the RB procedure (20 cases); therefore, a total of 3149 patients were retrospectively studied. Data included patient characteristics (age, gender, weight, respiratory system impairment), foreign body details (type, duration, location), whether anesthetic management or complications ever occurred, and interventions and outcomes. An active respiratory symptom was referred to the presence of abnormal clinical signs or laboratory examination as follows:

Address for correspondence: Dr. Wen-Xian Li, Department of Anesthesiology, Eye and ENT Hospital, Fudan University, 83 Fenyang Road, Shanghai 200031, China
E-Mail: wenxianli66@gmail.com

Wheezing symptoms with asthma history and/or pneumonia, atelectasis, or bronchiectasis diagnosed by a chest X-ray. The flow chart of the diagnostic algorithm of TFB aspiration in children at the EENT Hospital is shown in Figure 1.

Postoperatively pulmonary complications were defined as the existence of severe hypoxemia, laryngeal edema, complete laryngospasm, pneumothorax, atelectasis, and death.

Anesthetic method

Anesthesia was induced by inhalational or intravenous anesthetics. The former was performed by 8% sevoflurane in oxygen (6–8 L/min) aspiration, while the latter was accomplished by the infusion of fentanyl 1 μg/kg and propofol 2.5 mg/kg. Ventilation modes during anesthesia maintenance were divided into two types: (i) Controlled ventilation (CV), in which small bolus doses of succinylcholine 1 mg/kg were repeatedly administered to maintain muscle relaxation and total intravenous anesthesia (TIVA) with propofol (150–250 $\mu g \cdot kg^{-1} \cdot min^{-1}$) and remifentanil (0.1–0.2 $\mu g \cdot kg^{-1} \cdot min^{-1}$) infusion were used; and (ii) spontaneous ventilation (SV), in which inhalation or intravenous drugs were administered. The former was delivered using the sevoflurane approach (8% in oxygen inhalation) with a semi-circle anesthesia breathing circuit, whereas the latter was delivered by the intravenous induction of γ-hydroxybutyrate (50–80 μg/kg)[1] or dexmedetomidine (1–2 μg/kg) over 10 min followed by an infusion of 0.2–0.6 $\mu g \cdot kg^{-1} \cdot h^{-1}$. Prior to RB insertion, 2% lidocaine ($dose_{max}$ 4 mg/kg) was sprayed onto the epiglottis and larynx and between the vocal cords.

Techniques used

The choice of ventilation airway device was based on the anesthesiologist's experience and patients' circumstances. In patients with suspected subglottic TFB, an SV technique was used to avoid converting a proximal partial obstruction to a complete obstruction. The avoidance of positive ventilation was also used in cases of a definite preoperative mediastinum emphysema/pneumothorax for fear of inducing iatrogenic-related barotrauma. CV and SV are the two main techniques used during RB. CV is composed of intermittent positive pressure ventilation (IPPV) and manual jet ventilation (MJV). In the IPPV group, PPV

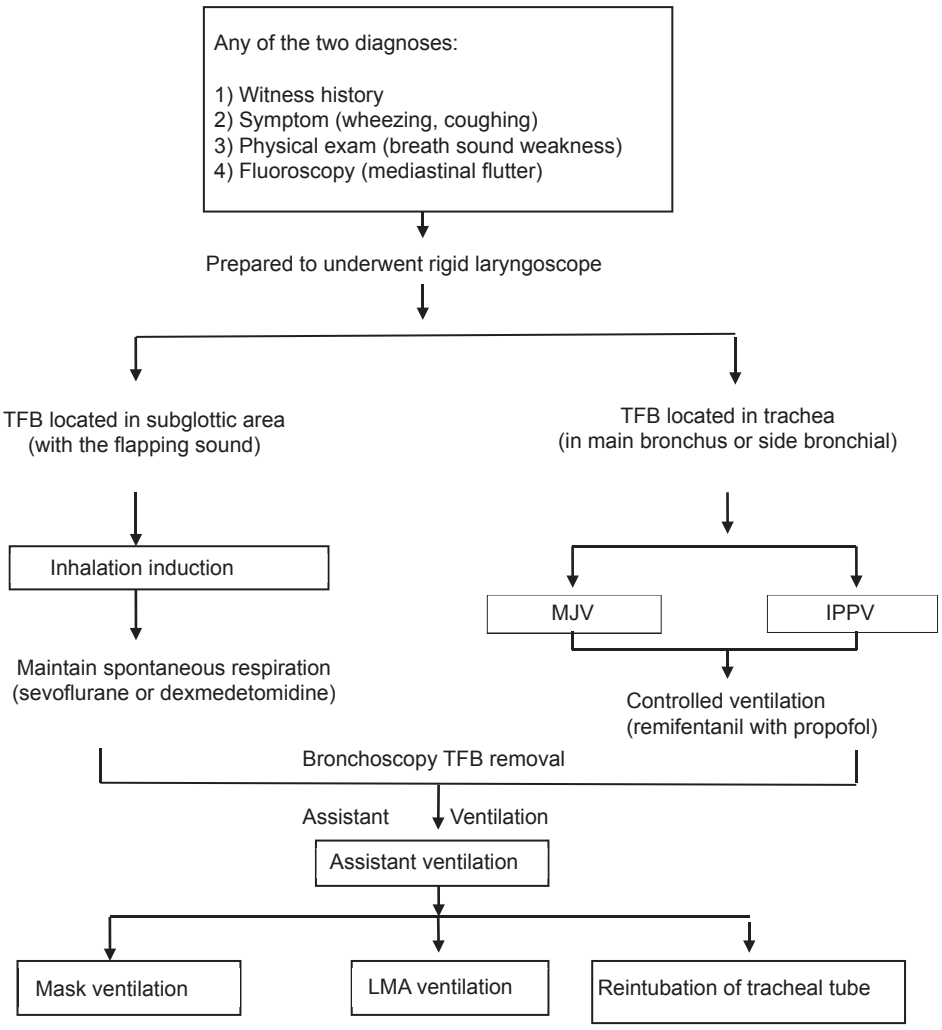

Figure 1: Diagnostic flow chart of TFB aspiration in children treated at the Eye and ENT Hospital. MJV: Manual jet ventilation; IPPV: Intermittent positive-pressure ventilation; TFB: Tracheobronchial foreign body; LMA: Laryngeal mask airway.

was commenced through the breathing circuit, which was connected as a T-shaped piece to the side arm of the RB (Storz, Tuttlingen, Germany). In the MJV group, jet ventilation (Manujet III, VBM, Sulz, Germany) was performed prior to insertion of the bronchoscope by the placement of a fine tube (inner diameter, 0.5 mm) transnasally into the trachea. Use of the MJV guarantees quick and efficient oxygenation during the procedure and has a high-pressure oxygen/air outlet that is adjustable to between 0.35 and 0.7 bar (5–10 psi). In the SV group, a spontaneously breathing patient received fresh gas through the lumen of the bronchoscope as well as by entrainment around the bronchoscope to enable exhalation in the same way.

Postoperative severe complications

The existence of atelectasis (segmental, lobar, or whole-lung) or pneumothorax was confirmed by chest X-ray due to a shadow in the area of a collapsed alveola or a collection of air or gas in the pleural cavity, respectively. Laryngeal edema caused by iatrogenic injury, especially with multiple bronchoscope insertions, appeared as hoarseness. A complete laryngospasm caused by an uncontrolled contraction of the laryngeal cords was confirmed clinically as a high-pitched crowing or silence while the glottis was totally closed, and the pulse oximetry (SpO_2) decreased to <85%. Severe hypoxemia was referred as a SpO_2 <80% lasting more than 30 s.

Anesthetic progress in our unit

The exploratory process of the general anesthetic technique featured four sequential time stages in our unit as follows.

Phase I

The first phase included 1991–1995 period of preliminary formation of the TFB surgery. Lacking experience to maintain both ventilation and anesthesia during the RB procedure, most patients underwent RB surgery only after the use of topical anesthesia. The otolaryngologist took the dominant role during the surgery and had to wear a ring hoop in the thumb to prevent being bitten. The anesthetists offered monitored anesthesia care during the RB procedure and used emergency intubation only in the case of a fatal episode.

Phase II

The second phase included the 1996–2004 period, a time of exploration when the proportion of general anesthesia was on the rise and use of the SV technique with γ-hydroxybutyrate, a hypnotic agent, due to its good respiratory and hemodynamic tolerance, was dominant. Patients breathe spontaneously during the procedure, but insufficient anesthesia depth always leads to body movements. Coughing and apnea are the most common causes of surgical suspension.

Phase III

The third phase included 2005–2008 period during which the CV technique was adopted as standard practice. Rapid sequence induction with short-term muscle relaxation (using succinylcholine) was used to facilitate insertion of the RB and CV was the main ventilation mode.

Phase IV

The fourth phase included the 2009–2010 period in which various induction and maintenance methods were used with rapid new anesthetics coming into use and the adoption of SV and CV, which comprised MJV and assisted ventilation (AV). Sevoflurane inhalation or dexmedetomidine infusion was used in the SV group, whereas in the latter two (MJV and AV group), a combination remifentanil–propofol TIVA in conjunction with succinylcholine was used to facilitate effective ventilation.

Phases III and IV are also called the modern technique periods.

Statistical analysis

Quantitative variables are presented as mean ± standard deviation (SD); qualitative data are expressed as a percentage of the total patient number. We created a histogram chart to show the quantity of surgery and general anesthesia number in aspirated patients who underwent RB [Figure 2] along with a comparison of various postoperative adverse effects during the four sequential periods [Figure 3]. We also explored the percentages of TFB (characteristic, retention) and surgical duration using pie charts [Figures 4-6]. The line charts in Figure 7 show the rate of increasing preoperative airway impairment, negative TFB findings and postoperative adverse events over a continuous interval (2005–2010) (n = 1971). The incidence of severe postoperative complications among patients with inhaled TFB according to ventilation mode (2005–2010) is shown. Fisher's exact test was used to examine categorical variables, and $P < 0.05$ was considered as statistically significant.

Results

Patient data

Data collected at the EENT Hospital included 3149 patients who accepted general anesthesia who accounted for >96% of all cases. TFB showed a gradual trend of the high incidence [Figure 2] with the increased proportion of general anesthesia. The average age was 3.92 years. Children <3 years of age dominated the population at 81.1% (n = 2272). TFB was confirmed in 85% (n = 2676) patients; of them, the successful extraction rate was 93% (n = 2489) by otolaryngologists. Correspondingly, the TFB could not be extracted by RB in 7% (n = 187) of patients due to the large incarceration or location within the lower lobe bronchus, in which cases a transfer to an adjacent chest hospital and a thoracotomy were needed.

Tracheobronchial foreign body characteristics

Peanut and plant seeds were the most common TFB (88.3%) detected in young children; in older children, other special materials (toy parts or bone) (40.0%) were common. Of the tracheobronchial TFB, most (41%) became lodged within the right mainstem, followed by the left mainstem (32%), trachea (22%), and subglottic region (5%). Retention of the TFB (mean 8.7 ± 14.2 days) was divided as follows: 0–7 days, 61%; 7–30 days, 26%; and >30 days,

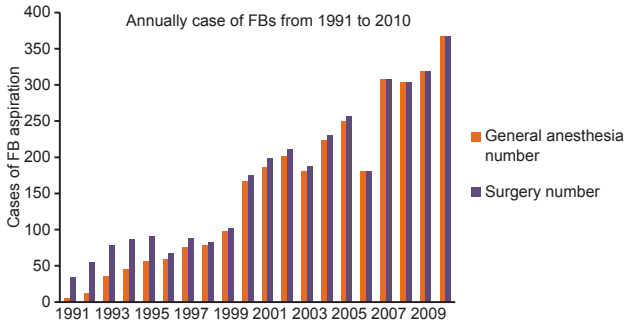

Figure 2: Annual cases of patients with a tracheobronchial foreign body who underwent rigid bronchoscopy at the Eye and ENT Hospital, 1991–2010 (3147 patients).

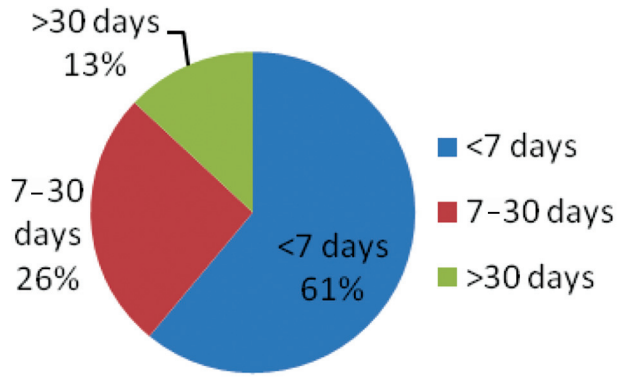

Figure 4: Time between tracheobronchial foreign body aspiration and presentation at the Eye and ENT Hospital.

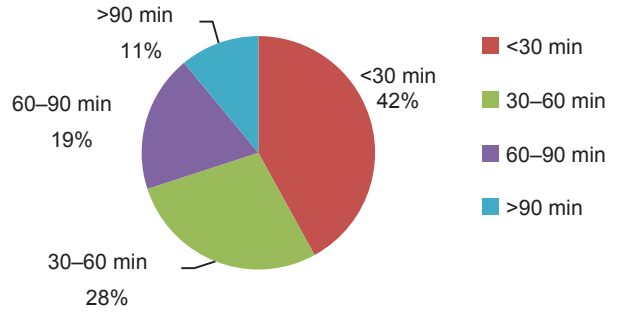

Figure 6: Duration of the rigid bronchoscopy procedure for tracheobronchial foreign body removal at the Eye and ENT Hospital (3147 patients).

13% [Figure 4]. The ranked sequence according to incidence is as follows [Figure 5]: Peanut (46.4%), seed (35.6%), food material (10.8%), Plastic material (2.1%), and needle (0.1%), while the remaining 15% (n = 473) of patients had negative findings that contributed to the misdiagnosis of foreign body aspiration.

Postoperative severe complications

Complications were seen in 9% (n = 284) of the patients: 87 (2.8%) had laryngeal edema, 109 (3.5%) had severe hypoxemia, 45 (1.4%) had complete laryngospasm, 23 (0.7%) had pneumothorax, 12 (0.4%) had atelectasis,

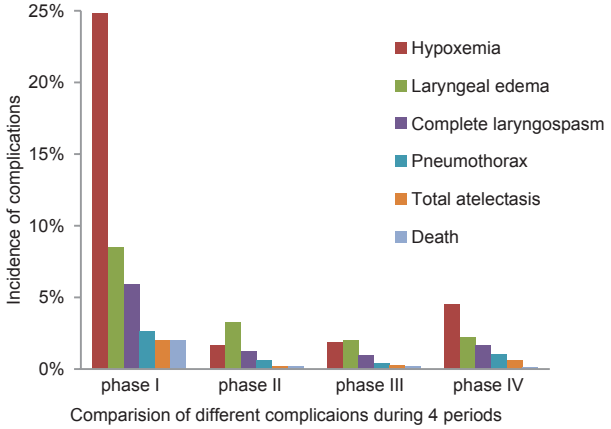

Figure 3: Incidence of severe postoperative complications among patients who inhaled a tracheobronchial foreign body during four sequential periods (n = 3147). Phase I (n = 341): Admitted 1991–1995; Phase II (n = 837): Admitted 1996–2004; Phase III (n = 1339): Admitted 2005–2008; Phase IV (n = 630): Admitted 2009–2010.

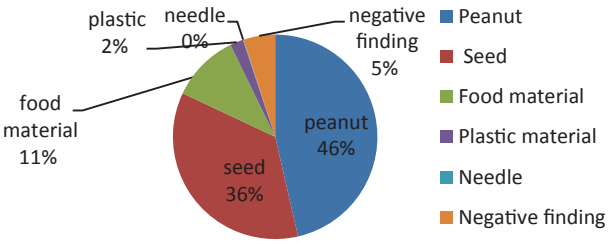

Figure 5: Type of tracheobronchial foreign body confirmed during rigid bronchoscopy at the Eye and ENT Hospital (3147 patients).

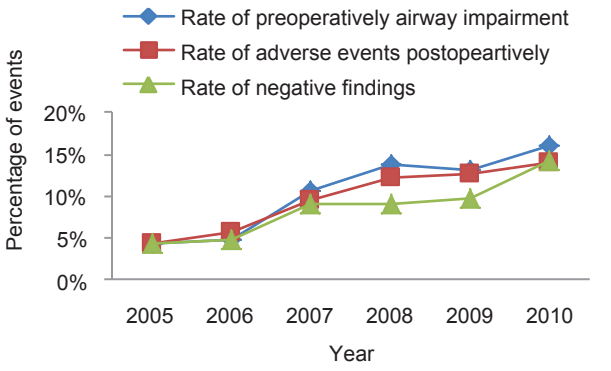

Figure 7: Rate of preoperative airway impairment, negative tracheobronchial foreign body and postoperative adverse events in 2005–2010 (n = 1728).

and 8 (0.3%) died postoperatively. Of the 23 patients with pneumothorax, two had severe postoperative hypoxemia (cyanosis) in an emergency situation in whom an intercostal drain tube was placed by an anesthetist. Adverse events also led to discharge delay (>2 weeks in 25 patients), critical care admission (in 8 patients), and eight postoperative deaths. In the period of 2005–2010, for example, the rates of the negative finding of TFB and postoperative adverse events tended to increase progressively with the rate of observed

preoperative active airway symptoms [Figure 7], showing that the overall prevalence of airway impairment was high in patients with negative findings (48.1%).

Discussion

Foreign body aspiration is the most common cause of toddler emergencies in otolaryngology services. The RB, proved to be the most classic choice for TFB extraction,[2,3] remains the standard diagnostic and therapeutic method at our hospital. The RB procedure presents the challenge of a shared airway and the hazard of a postoperatively compromised airway, especially in some extreme instances that may progress to lethal complications.

When analyzing the population, we made the remarkable discovery that >95% of the patients coming from rural areas. In recent years, with the development of city construction in China, the "tide sweeps into big cities for better work" caused many farmers to migrate from rural areas to downtown. In their hometowns, the supervisory responsibility of small children was transferred to the grandparents, who not only lack the ability to care for toddlers but also feed these young children the same food they eat (vegetable materials or seeds). These factors affected the epidemiological characteristics.

The reasons for annual quantitative increases in surgical interventions and general anesthesia [Figure 2] are as follows: (1) With the recent implementation of the first diagnosed responsibility system in China, patients with clinically suspicious TFB aspiration are transferred directly to our institution from other hospitals. (2) Out of fear of a missed diagnosis of TFB, the RB was performed even in patients with normal physical findings or wheezing breath sounds with the final diagnosis of asthma or pneumonia, which caused the increased severe postoperative complications.

In our series, the average duration of symptoms with suspected TFB was 8.7 ± 14.2 days, relatively high compared to the results presented by previous reports. More than 10% of patients had symptoms for >30 days [Figure 4], and the longest TFB retention was 375 days.[4,5] The longer time before diagnosis of TFB aspiration was due in part to atypical symptoms or misdiagnosis with other diseases such as pneumonia or asthma, and the latter is commonly seen in patients with a history of allergic airway disease who lack a typical syndrome.[6] In some cases, the referred patients were treated in other hospitals before being admitted to our center.

Foreign body aspiration can mimic other respiratory problems such as asthma[7-9] with the same clinical symptoms of coughing, wheezing, and choking, especially in absence of an aspiration witness. Preoperative positive respiratory disease not only led to a high incidence of misdiagnosis, but also resulted in improper surgical intervention, which put patients at increased risk of postoperative adverse events due to airway irritation.[10] In our study, approximately 48.1% of children with preoperative airway impairment developed postoperative airway events. The results demonstrated that the preoperative active respiratory symptom may have a low value for diagnosing TFB, but a high predictive value for predicting postoperative adverse events.

The complications of hypoxemia and laryngeal edema were evenly spread between the CV and SV technique groups, and there was a high incidence of complete laryngospasm in the SV group [Table 1]. As reviewed by Roberts and Frca,[11] a spontaneous respiration should be best preserved during the bronchoscopic extraction of inhaled foreign bodies with the benefits of excellent visual conditions and successful surgical rates. However, the sample size of the SV group was insufficient to draw any conclusions. Pneumothorax, which is treated by pleural cavity drainage, had a higher incidence in the MJV group than in the IPPV group, but the difference did not reach statistical significance. In some cases, the fine tube may slide into the lateral bronchi with the consequences of single-lung ventilation and iatrogenic injury. It should be highlighted that a precautionary step should be taken in Manujet ventilation, although with its locking mechanism unlike automatic ventilators, the ventilation cannot be automatically cut off when peak or pause airway pressure is increased.

A long-retained TFB may cause the production of arachidonic acid, which results in an abnormal secretion of mucus and exudate that plugs up the lungs.[12] The persistent accumulation may lead to inflammation and infection as well as atelectasis or obstructive pneumonia in clinically presentation. Some studies reviewed the clinical and management aspects of TFB aspiration and found that delayed diagnosis caused more common severe post-bronchoscopy complications that create significant morbidity.[13,14]

During the past 2 years (2008–2010), there is an obvious increase in the rates of preoperative airway impairment, negative findings of TFB, and postoperative adverse events. In our hospital, after an accident death of misdiagnosed TFB in 2008 (the patient was diagnosed with pneumonia but later died of total subglottal foreign body obstruction), the Medical Services Section set an enforced rule that every pediatric patient with suspected airway aspiration

Table 1: Incidence of severe postoperative complications among patients with inhaled tracheobronchial foreign body inhalation by ventilation mode in 2005-2010 (n=1728)

Complications	Ventilation mode (%)		RR (95% CI)	P
	CV group (n=1501)	SV group (n=227)		
Severe hypoxemia	77 (5.1)	11 (4.8)	0.68 (0.42–1.85)	0.214
Laryngeal edema	21 (1.4)	3 (1.2)	0.43 (0.23–1.25)	0.521
Complete laryngospasm	27 (1.8)	8 (3.5)	0.65 (0.53–1.76)	0.256
Pneumothorax	7 (0.47)	1 (0.4)	0.23 (0.14–1.47)	0.843
Atelectasis	7 (0.47)	1 (0.4)	0.24 (0.11–1.54)	0.561
Death	4 (0.27)	0	0.54 (0.26–1.73)	0.053

CV: Controlled ventilation; SV: Spontaneous ventilation; RR: Relative risk; CI: Confidence interval.

symptoms (coughing, choking with or without a mediastinal swing) after either initial diagnosis or referral should undergo diagnostic RB. The policy may relate to the higher negative exploration rate because the unnecessary procedures are on the rise.

Our study may have certain limitations despite its meaningful results. First, as an observational study, although it described the characteristics of TFB aspiration and associated anesthetic considerations, it did not consider the progress of anesthetic and surgical techniques over the study period, so the design may overestimate the effect of an intervention that can decrease postoperative adverse effects. Second, the lack of comparison among different airway support methods after TFB retrieval, either with a supraglottic airway or invasive airway, may also contribute to the postoperative adverse events. Third, in cases of standardization scheme shortage, individual proposals among the surgery team are prevalent during RB, which may create information bias.

There are no guidelines for best anesthetic practice in the management of RB in patients with inhaled TFB. Our center performs >300 RB procedures per year. Our findings suggest that neither ventilation technique showed a definitely good safety profile that features a low incidence of respiratory complications during a postoperative emergency. In addition, the results should encourage anesthesiologists to continue to seek new techniques for reducing the potential risk during the RB procedure in patients with TFB as much as possible.

In summary, we experienced a series of processes that included topical anesthesia, SV anesthesia, CV anesthesia, and multi-ventilation anesthesia. After TFB extraction, careful airway management should be ensured by the anesthetist. Our future work may focus on a standard workflow model designed to alleviate complications caused by an inadequate perioperative anesthesia state.

References

1. Snead OC 3rd, Gibson KM. Gamma-hydroxybutyric acid. N Engl J Med 2005;352:2721-32.
2. Pasaoglu I, Dogan R, Demircin M, Hatipoglu A, Bozer AY. Bronchoscopic removal of foreign bodies in children: Retrospective analysis of 822 cases. Thorac Cardiovasc Surg 1991;39:95-8.
3. McGuirt WF, Holmes KD, Feehs R, Browne JD. Tracheobronchial foreign bodies. Laryngoscope 1988;98:615-8.
4. Yadav SP, Singh J, Aggarwal N, Goel A. Airway foreign bodies in children: Experience of 132 cases. Singapore Med J 2007;48:850-3.
5. Gurpinar A, Kilic N, Dogruyol H. Foreign body aspiration in children. Turk Respir J 2003;4:131-4.
6. Baharloo F, Veyckemans F, Francis C, Biettlot MP, Rodenstein DO. Tracheobronchial foreign bodies: Presentation and management in children and adults. Chest 1999;115:1357-62.
7. Caglayan S, Erkin S, Coteli I, Oniz H. Bronchial foreign body vs asthma. Chest 1989;96:509-11.
8. Tan HK, Brown K, McGill T, Kenna MA, Lund DP, Healy GB. Airway foreign bodies (FB): A 10-year review. Int J Pediatr Otorhinolaryngol 2000;56:91-9.
9. Kugelman A, Shaoul R, Goldsher M, Srugo I. Persistent cough and failure to thrive: A presentation of foreign body aspiration in a child with asthma. Pediatrics 2006;117:e1057-60.
10. Zhang X, Li W, Chen Y. Postoperative adverse respiratory events in preschool patients with inhaled foreign bodies: An analysis of 505 cases. Paediatr Anaesth 2011;21:1003-8.
11. Roberts S, Frca M. Paediatric bronchoscope. Contin Educ Anaesth Crit Care Pain 2005;5:41-4.
12. Fahy JV, Dickey BF. Airway mucus function and dysfunction. N Engl J Med 2010;363:2233-47.
13. Ibrahim Sersar S, Hamza UA, AbdelHameed WA, AbulMaaty RA, Gowaeli NN, Moussa SA, *et al.* Inhaled foreign bodies: Management according to early or late presentation. Eur J Cardiothorac Surg 2005;28:369-74.
14. Saquib Mallick M, Rauf Khan A, Al-Bassam A. Late presentation of tracheobronchial foreign body aspiration in children. J Trop Pediatr 2005;51:145-8.

Received: 04-12-2014 **Edited by:** Xiu-Yuan Hao
How to cite this article: Zhang X, Li WX, Cai YR. A Time Series Observation of Chinese Children Undergoing Rigid Bronchoscopy for an Inhaled Foreign Body: 3149 Cases in 1991-2010. Chin Med J 2015;128:504-9.

Source of Support: This study was supported by the Social Development Research Project in Shanghai (Grant number STCSM2014-14411969700 to Wen-Xian Li). **Conflict of Interest:** None declared.