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ORIGINAL ARTICLE

A retrospective study of anesthesia during rigid bronchoscopy for airway foreign body removal in children: propofol and sevoflurane with spontaneous ventilation

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Summary

Background: Tracheobronchial foreign body aspiration is a significant cause of childhood morbidity and mortality. We analyzed our experience in management of aspirated foreign bodies, including methods of anesthesia used, over a 4-year period.

Methods: We retrospectively reviewed the records of tracheobronchial foreign body removal by rigid bronchoscopy with spontaneous ventilation in 435 children. All patients had received initial anesthesia with inhaled sevoflurane. One hundred and ninety-seven patients (Group PropRemi) then received intravenous propofol and remifentanyl for maintenance of anesthesia; the remaining 238 patients (Group PropSevo) received propofol and sevoflurane.

Results: Tracheobronchial foreign body was found in 405 children (93.1%) and successfully removed from 402 (99.3%) children. Among three patients who failed bronchoscopy, one child suffered cardiac arrest and died during the bronchoscopy, and two required subsequent tracheotomy for foreign body removal. Adverse effects (intraoperative coughing, breath holding, body movement, bronchospasm, and laryngospasm) were significantly more frequent in Group PropRemi than in Group PropSevo. No complications such as bleeding, pneumothorax, pneumomediastinum, or the need for thoracotomy were encountered.

Conclusion: Sevoflurane induction followed by a combination of sevoflurane and continuous infusion of propofol resulted in fewer adverse events than sevoflurane induction followed by TIVA with propofol and remifentanyl during rigid bronchoscopy for airway foreign body removal in children with spontaneous ventilation.

Introduction

Tracheobronchial foreign body aspiration is a common pediatric emergency and a significant cause of childhood morbidity and mortality (1–3). Undiagnosed or delayed treatment of a tracheobronchial foreign body can result in pneumonia, atelectasis, lung abscess, or distal dislocation of the body, with fatal airway obstruction (4–6). Early diagnosis and extraction of a tracheobronchial foreign body can decrease the incidence of complications. Rigid bronchoscopy is the standard method for confirming the presence of a tracheobronchial foreign body in children and removing it (7–9).

Rigid bronchoscopy in children usually is performed under general anesthesia because they may be uncooperative during the procedure. It is our usual practice to perform the procedure with spontaneous ventilation because of its better ventilation/perfusion ratio, more effective alveolar ventilation and lack of ventilator-associated lung injury. A literature review in 2010 (10) showed that the mortality rate among children with aspirated foreign bodies was 0.4%. In

China, tracheobronchial foreign body aspiration in children is mostly due to dietary and feeding customs (11). In recent years, the incidence has declined due to health education, but still remains high among children in rural areas.

Our hospital is a tertiary care institution in Liaoning Province in northeast China and the largest pediatric center in the region. The province has a population of 43 million, and our hospital sees slightly more than 100 000 patients in otolaryngology every year during 2009–2012, and slightly more than 3000 cases of operations are performed every year. The hospital has 135 beds in otolaryngology, and approximately 80% of the children with aspirated foreign bodies in Liaoning province are treated at our hospital. In this retrospective review, we presented our experience in the management of tracheobronchial foreign body aspiration in pediatric patients over a 4-year period in our hospital, with emphasis on two methods of anesthesia used (intravenous anesthesia and intravenous plus inhaled anesthesia) with spontaneous ventilation.

Patients and methods

Patients

We retrospectively analyzed the medical and surgical records of 497 consecutive children who sought treatment at the Department of Anesthesiology and Otorhinolaryngology, Shengjing Hospital, China Medical University, Shenyang, China for suspected tracheobronchial foreign body aspiration between January 2009 and December 2012. Patient age, gender, weight, time from aspiration to seeking treatment, preoperative complications, type, and location of extracted foreign body, anesthesia management (the method of anesthesia, monitoring, and complications), and duration of hospital stay were reviewed. Patients ($n = 62$) who had incomplete data or associated anomalies were not eligible for inclusion in the study. Hypoxemia was defined as $SpO_2 < 90\%$ and longer than 15 s; laryngospasm was diagnosed when glottal closure was present that blocked the passage of air to the lungs and characterized by stridor and/or retractions. Bronchospasm was considered present with prolonged expiratory phase and wheezes.

The study protocol was approved by the Hospital Human Research Committee of the affiliated Shengjing Hospital, China Medical University, Shenyang, China. Informed consent for the procedure was obtained from the parents or legal guardian before anesthesia. Parent or guardian consent for the retrospective study was not required as only lumped anonymous data were reported.

Rigid bronchoscopy

Rigid bronchoscopy was performed on all of the children suspected of tracheobronchial foreign body aspiration. Children fasted for 6 h before the procedure. Their heart rate, blood pressure, electrocardiogram, respiratory rates, and pulse oxygen saturation (SpO_2) were monitored regularly. For all patients, anesthesia was induced by inhalation of sevoflurane in 100% O_2 at 4–5 $l \cdot min^{-1}$ and sevoflurane was inspired in stepwise increments of 1.5% every three breaths up to a maximum of 8%. After unconsciousness was achieved, an intravenous access line was inserted and atropine (0.01 $mg \cdot kg^{-1}$) was given intravenously. The vaporizer of sevoflurane was switched off in 197 children (hereafter referred to as Group PropRemi), and propofol at 100–150 $\mu g \cdot kg^{-1} \cdot min^{-1}$ and remifentanyl at 0.1–0.2 $\mu g \cdot kg^{-1} \cdot min^{-1}$ were constantly infused. In 238 patients (Group PropSevo), 2–5% sevoflurane and 100% O_2 2–3 $l \cdot min^{-1}$ were continued to keep the respiratory rate and hemodynamics stable, and propofol was administered intravenously at a constant rate of 100–150 $\mu g \cdot kg^{-1} \cdot min^{-1}$. In all patients, if there was no movement when laryngoscopy was performed, lidocaine (1%; 2 $mg \cdot kg^{-1}$) was sprayed on the supraglottic and glottic structures, and into the trachea via a laryngeal tube. Additional propofol 0.5–1 $mg \cdot kg^{-1}$ was given as needed to deepen anesthesia. When the respiratory rate had declined to 50% of baseline value and there was no movement within 3 min of lidocaine application, the instruments were inserted through the glottic opening. Rigid bronchoscopy and extraction of the foreign body were performed by experienced otorhinolaryngologists. In Group PropSevo, the anesthesia circuit was connected to the side port of the bronchoscope to allow the inhalation of sevoflurane and oxygen. Assisted ventilation was provided if SpO_2 declined below 90%.

After removal of the aspirated tracheobronchial foreign body, the bilateral bronchi were inspected carefully. A small catheter was inserted through the main lumen of the bronchoscope to measure endtidal CO_2 partial pressure ($PEtCO_2$), and the tip of the catheter was positioned 10 cm from the distal end of the rigid bronchoscope. Inhalation of sevoflurane and O_2 was stopped for 2 min during the measurement. After the instrument was removed, assisted ventilation was performed with facemask at 100% O_2 until stable spontaneous ventilation returned and SpO_2 remained above 95% on room air. Young children and infants were transferred to the postanesthesia care unit (PACU) for recovery, where they were monitored carefully for at least one-half hour after becoming fully awake. All patients received a postoperative chest radiograph the next day and were given

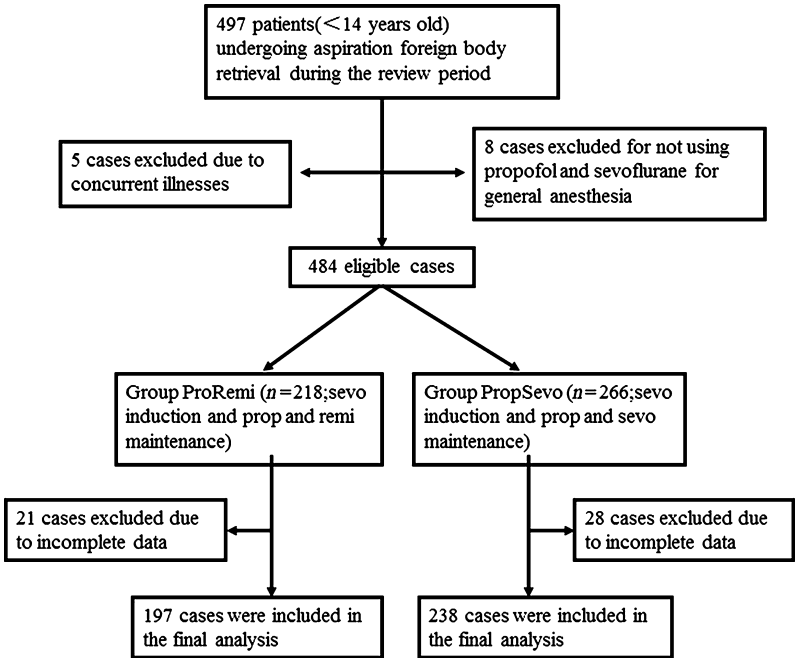

Figure 1 The study flowchart.

antibiotics. Patients who had developed laryngeal edema or bronchospasm during bronchoscopy were given anti-inflammatory steroid medication for 24–48 h.

Statistical analysis

All data were analyzed using the SPSS version 11.5 (Chicago, IL, USA). Normally distributed data are reported as mean ± SD, and Student's *t*-test was used for comparison between the two groups. Numerical data are reported as numbers or percentages, and comparisons between the groups were performed with Pearson's χ^2-test. Nonnormally distributed data are reported as median and interquartile range. A P value <0.05 was considered statistically significant.

Table 1 Clinical characteristics of the patients

	Group PropRemi[a] *n* = 197	Group PropSevo[b] *n* = 238
Age (months)	24.2 (17.0–25.0)	23.4 (16.0–27.0)
Male gender	110 (55.8)	134 (56.3)
Body weight (kg)	13.2 (10.5–14.5)	11.9 (10.5–13.5)
Time from event to hospital admission for foreign body (days)	10.2 (2.0–15)	8.9 (1.0–7.0)
Pneumonia before hospitalization, *n* (%)	62 (31.5)	80 (33.6)
Type of foreign bodies, *n* (%)		
Organics	184 (93.4)	228 (95.8)
Inorganic	13 (6.6)	10 (4.2)

The data are presented as mean ± SD, percentage or median and interquartile range.

[a]Maintenance anesthesia with propofol and remifentanyl.

[b]Maintenance anesthesia with propofol and sevoflurane.

Results

The study flowchart is shown in Figure 1. Totally, 435 children had complete clinical data and were included in the study. Tracheobronchial foreign body was found in 405 children (93.1%). The aspirated foreign body was successfully removed from 402 children (99.3%). In three cases, bronchoscopy removal failed. Demographic and baseline characteristics did not differ between groups. Most of the foreign bodies (Group PropRemi, 93.4% and Group PropSevo, 95.8%) were organic, such as peanuts, sunflower seeds, hazelnuts, watermelon seeds, and pine nuts; others were inorganic, such as whistles, pen caps, and tiny toys (Table 1). The median time from event to hospital admission was 10.2 (IQR, 2.0–15) days for Group PropRemi, and 8.9 (IQR, 1.0–7.0) days for Group PropSevo. Approximately one-third of the children had pneumonia before admission (Group PropRemi, 31.5% and Group PropSevo, 33.6%).

The characteristics and outcome of the bronchoscopies are listed in Table 2. The duration of the procedures and emergence from anesthesia did not differ between the two groups. More than half of foreign bodies (59.3%) were found in the right bronchial tree, 34.9% in the left bronchial tree, and 5.8% in other parts of the airway, such as the trachea and supralarynx. $P_{Et}CO_2$

Table 2 The characteristics of and outcome of bronchoscopies

	Group PropRemi[a] $n = 197$	Group PropSevo[b] $n = 238$
Duration of operation (min)	25 ± 12	22 ± 13
Duration of emergence from anesthesia (min)	9 ± 5	9 ± 4
Location of foreign body, *n* (%)		
Right bronchus	113 (57.4)	146 (61.3)
Left bronchus	70 (35.5)	82 (34.5)
Main bronchus and others	14 (7.1)	10 (4.2)
$P_{Et}CO_2$ (Kpa)	6.92 ± 4.37	6.51 ± 4.08
Hospital stay (days)	2.5 ± 3.1	2.8 ± 4.6

The data are presented as mean ± SD or percentage.
[a]Maintenance anesthesia with propofol and remifentanyl.
[b]Maintenance anesthesia with propofol and sevoflurane.

Table 3 Adverse events during rigid bronchoscopy in the two groups

Adverse events (case)	Group PropRemi[a] $n = 197$	Group PropSevo[b] $n = 238$
Cough	55 (27.9)	26 (10.9)*
Breath holding (<10 s)	32 (16.2)	13 (5.5)*
Hypoxemia ($SpO_2 < 90\%$)	56 (28.4)	37 (15.5)*
Body movement	43 (21.8)	18 (7.6)*
Laryngospasm	34 (17.3)	16 (6.7)*
Bronchospasm	18 (9.1)	8 (3.4)*
Tracheotomy	1 (0.5)	1 (0.4)
Cardiac arrest	0	1 (0.4)

The data are presented as number of cases and percentage.
[a]Maintenance anesthesia with propofol and remifentanyl.
[b]Maintenance anesthesia with propofol and sevoflurane.
*$P < 0.05$ compared with the other group.

measured before the bronchoscopy was slightly but not statistically significantly higher in Group PropRemi than in Group PropSevo patients. The hospital stay of both groups was similar.

The perioperative adverse events are listed in Table 3. Intraoperative cough, breath holding, hypoxemia, body movement, laryngospasm, and bronchospasm were significantly more frequent in Group PropRemi than in Group PropSevo. One patient in each group required tracheotomy because the aspirated foreign bodies could not be extracted through the rigid laryngoscope; one of the foreign bodies was a plastic whistle, and the other a tiny toy ball. One child died of severe airway obstruction and cardiac arrest during the procedure. No other severe complications, such as bleeding, pneumothorax, pneumomediastinum, or the need for thoracotomy occurred.

Discussion

In this study, we retrospectively reviewed 435 cases of children undergoing rigid bronchoscopy for removal of aspirated tracheobronchial foreign bodies with general anesthesia. The objects were successfully removed in nearly all children in whom a foreign body was found at bronchoscopy. Anesthesia was induced in all patients with sevoflurane and maintained either with intravenous agents only (propofol and remifentanyl) or with a combination of intravenous propofol and sevoflurane. We used spontaneous ventilation for our patients and achieved a high rate of removal of the foreign bodies and had a low rate of interfering coughs and body movement. No serious airway trauma or rupture was encountered. Significantly fewer adverse events occurred with the use of combined sevofluorane and propofol than with the two intravenous agents, propofol and remifentanyl alone.

Inhaled anesthesia and total intravenous anesthesia are widely used for rigid bronchoscopy in children (12,13). Chen *et al.* (14) found a higher incidence of body movement, breath holding, and laryngospasm with total intravenous anesthesia and spontaneous ventilation compared with an inhaled technique. Inhaled anesthesia is popular for use in the pediatric population, but it may be associated with hypoventilation and leaks around the bronchoscope, resulting in an inadequate depth of anesthesia. Moreover, the volatile agents can pollute the operating room air (15). Based on our experience, we feel that combined anesthesia, with sevoflurane and propofol, plus topical lidocaine, is an appropriate regimen for rigid bronchoscopy. We gave our patients a bolus of propofol in addition to the continually infused propofol as the bronchoscope was inserted into the trachea or body movement occurred during the procedure. Body movement and coughing became more frequent when the duration of bronchoscopy exceeded 30 min, probably in part because topical lidocaine anesthesia gradually diminished over time. We found that topical lidocaine applied to the oropharynx, supraglottic, and glottic structures, and the trachea was helpful and reduced the amount of anesthetics needed during the procedure, an observation consistent with those by others (16).

We found a lower incidence of breath holding in Group PropSevo than in Group PropRemi. This may be due to the muscle relaxing effect by sevoflurane which may subdue the reflex response of the glottis to external stimuli (17). This is consistent with the findings by Liao *et al.* (18) who found the incidence of breath holding and desaturation was lower in pediatric patients undergoing foreign body removal under sevoflurane

inhalation than that of children under intravenous propofol and remifetanyl anesthesia. We also found that, even though desaturation and CO_2 retention are common complications during general anesthesia with spontaneous ventilation, our patients had only slightly increased $EtCO_2$ after the foreign body was removed, and serious hypoxemia was seldom present during the procedure or in the PACU. It has been reported that minute volume or $P_{Et}CO_2$, anesthesia depth are well correlated with variations in the respiratory rate during general anesthesia with spontaneous ventilation (19). A 50% decrease in respiratory rate from baseline has been considered a suitable anesthesia depth for rigid bronchoscopy (12).

The mortality rate in our series (0.23%) is consistent with that in other reports (0.42%) (1,20,21), in which death occurred as a result of respiratory failure and cardiac arrest (10). One of our children developed cardiac arrest and died from total tracheal obstruction because of an aspirated pen cap, even though the child was transported to the emergency center and emergent tracheotomy was performed. Two other children were successfully treated by tracheotomy after tracheal foreign bodies could not be removed; one had obstruction of the hypolarynx with a plastic whistle, and the other had similar obstruction with a tiny toy ball. We attribute the absence of other severe complications to our having a structured program for dealing with foreign body aspiration, including preoperative preparation for possible intubation, tracheostomy, or thoracotomy.

In our series, 32.8% of the children presented with pneumonia or pulmonary emphysema before their hospitalization, and the time from suspected aspiration of a foreign body to hospital presentation was quite long (>5 days), and longer than that in other studies (1,7). The delay in making the diagnosis probably was a consequence of poor health education and initial failure to make the diagnosis in rural hospitals, where patients often were treated for pneumonia only for a few days before being transferred to our hospital. The delay in recognizing the presence of a foreign body aspiration may have led to bronchial mucosal damage, resulting in more time-consuming bronchoscopy and longer duration of hospitalization than others have reported; Tomaske *et al.* (7) had median procedure duration of 15 min and hospitalization of 2–12 h.

Limitations

There were a few limitations in our study. The study was retrospective and did not have controls, and the patients were not randomized. Propofol was maintained by infusion at a constant pump rate, rather than by target controlled injection, so the depth of anesthesia was not as uniform as desired, and it is reasto assume that anesthetic depth varied during the procedures and may have been different between the two groups. Furthermore, we did not have a means of accurately assessing depth of anesthesia.

Conclusions

This retrospective review of 435 cases of anesthesia for foreign body extraction using rigid bronchoscopy in children indicates that sevoflurane induction followed by a combination of sevoflurane and continuous infusion of propofol resulted in fewer adverse events than sevoflurane induction followed by TIVA with propofol and remifentanyl.

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Conflict of interest

No conflicts of interest declared.

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