ORIGINAL ARTICLE

Anesthesia with propofol-remifentanil combined with rocuronium for bronchial foreign body removal in children: Experience of 2 886 cases

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ABSTRACT

Importance: The appropriate anesthetic method can reduce the complications of children with tracheal foreign body and reduce the mortality rate of children. What kind of anesthetic method to choose has always been the focus of debate.

Purpose: To evaluate the efficacy and safety of anesthesia with propofol-remifentanil combined with rocuronium for foreign body aspiration (FBA) removal with the positive-pressure ventilation technique.

Methods: Medical records of patients who underwent bronchoscopy for evaluation of FBA in our unit from January 2015 to January 2018 were retrospectively reviewed. Demographic data (age and sex), nature of foreign body and location, complications, length of hospital stay and outcome were analyzed.

Results: A total of 2 886 children were included in this study. The median age was 24 months (8 months to 10 years). FBA was detected and removed in 95.6% of patients. The average operation time was 17 ± 5 min and average length of hospital stay was 2 days. Observed peri-interventional complications included desaturation (n = 66), laryngospasm (n = 19), laryngeal or subglottic edema (n = 15), irritating cough (n = 3), body movement (n = 76) and pneumonia (n = 206). No deaths occurred during hospitalization or follow-up in this series.

Interpretation: Anesthesia with propofol-remifentanil combined with rocuronium under positive-pressure ventilation is an effective and safe technique during FBA removal in children.

KEYWORDS
Anaesthesia, Foreign body aspiration, Rigid bronchoscopy, Rocuronium, Positive-pressure ventilation

INTRODUCTION

Foreign body aspiration (FBA) is a common pediatric emergency. Early removal of the foreign body can reduce the occurrence of complications and lower the mortality rate.[1,2] The gold standard for the diagnosis and management of this condition is rigid bronchoscopy under general anesthesia with spontaneous ventilation or pressure-control ventilation. Sevoflurane or propofol-remifentanil for anesthesia with spontaneous ventilation for FBA removal is commonly used in many hospitals.[3-5] However, one disadvantage of spontaneous ventilation is

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that the anesthetic depth cannot be precisely controlled to reduce body movement and airway reflex like cough, laryngospasm or bronchospasm.[6] In addition, increased resistance to ventilation using telescope worsens hypoxemia. The muscle-relaxant technique can provide an even and adequate depth of anesthesia for rigid bronchoscopy and decrease anesthetic effects on cardiac output.[7,8] In addition, positive-pressure ventilation may decrease atelectasis, improve oxygenation and overcome increased airway resistance that occurs when a telescope is used.

In the present study, the medical records of 2 886 patients within the past 3 years were retrospectively reviewed to evaluate the efficacy and safety of anesthesia with propofol-remifentanil combined with rocuronium for FBA removal under positive-pressure ventilation.

MATERIALS AND METHODS

Subjects

A total of 2 886 children undergoing FBA removal under rigid bronchoscopy at our hospital from January 2015 to January 2018 were included. Approval was obtained from the hospital ethical committee. All patients were followed up by telephone 2 weeks after discharge.

The following patient information was collected and analyzed: demographic data (age and sex), nature of foreign body and location, complications including laryngospasm, laryngeal or subglottic edema, mucosal bleeding and low saturation of blood oxygen (pulse oxygen saturation, SpO_2 <90% lasting for more than 5 s), length of hospital stay and outcome.

Anesthesia management

Patients fasted for 6 h before the procedure. All children had topical local anesthetic lidocaine cream applied to the skin of the lower limb 30 min before the establishment of intravenous access, and received intravenous premedication with 0.1 mg/kg midazolam 30 min before induction of anesthesia. On arrival at the operating room, all patients were monitored the electrocardiogram, blood pressure, SpO_2, bispectral index (BIS), endtidal CO_2 partial pressure ($PEtCO_2$) with a monitor (PHILIPS IntelliVue MP70, Germany).

After rapid induction with 2 mg/kg propofol, 1–1.5 μg/kg remifentanil, 0.45 mg/kg rocuronium, anesthesia was continued to maintain BIS values between 40 and 60 with propofol infusion 8–12 mg/kg/h and remifentanil infusion 10–15 mg/kg/h. Oxygen (3 L/min) was delivered by a facemask.

The neuromuscular block following rocuronium was monitored using electromyography. Surface electrodes were placed near the wrist to stimulate the ulnar nerve by using train-of-four (TOF) stimulation (2 Hz every 12 s). The onset time [from application of rocuronium to maximum depression of the first twitch height in TOF stimulation (T1)], clinical duration (from application to 25% recovery of T1) and time to full spontaneous recovery (from application to TOF-ratio ≥ 0.9) were determined for each patient.

After jaw relaxation, an appropriately sized rigid ventilating bronchoscope of 2.5–5.5 mm internal diameter (Karl-Storz system) was inserted by an experienced otorhinolaryngologist. Pressure-control ventilation was used via a ventilator (Datex Ohmeda S/5 Avance, GE, USA) that connected to the lateral aperture on the rigid bronchoscope to maintain SpO_2 (pulse oximetry) >95%. The partial pressure of oxygen in blood (PaO_2), partial pressure of carbon dioxide in blood ($PaCO_2$) and SaO_2 were monitored by blood gas analysis.

After FBA removal, secretions were washed away with normal saline, and the bronchial tree was carefully examined. After removal of the bronchoscope, the patient's breathing was controlled by laryngeal mask airway (LMA) before the recovery of spontaneous breathing (tidal volume 8–10 mL/kg, respiratory rate 20–30 bpm and SpO_2 >95% without LMA) and TOF-ratio ≥ 0.9. The children were constantly monitored in the post-anesthesia care unit until fully awake.

RESULTS

All 2 886 cases in our study received general anesthesia with propofol-remifentanil combined with rocuronium. FBA was found and successfully removed in 2 760 cases and no FBA was found in the remaining 126 cases. The average age was 24 months (range from 8 months to 10 years). Most cases were in the age group of 1–3 years (68.5%) (Table 1).

TABLE 1 Patient characteristics (N = 2 886)

Patient data	Cases	Percentage (%)
Ages		
≤1 years	789	27.3
1–3 years	1 963	68.1
≥3 years	134	4.6
Gender		
Male/female	1 733/1 153	60%/40%
Weight		
≤10kg	678	23.5
10–20kg	2 130	73.8
≥20kg	78	2.7
Time to diagnose		
<1days	626	21.7
1–7 days	1 362	47.2
7–30 days	531	18.4
≥30 days	367	12.7

Of the 2 760 FBAs, 1 669 (60.5%) were located in the right bronchus, 783 (28.4%) in the left bronchus, 171 (6.2%) in the tracheal bifurcation, 63 (2.3%) in the subglottic larynx and 74 (2.7%) in both lungs (Table 2). Most FBAs in our study were foods such as peanuts, sunflower seeds, watermelon seeds, beans, popcorn and bone fragments. However in older children, other kinds of FBAs such as small toy parts, caps and balloon debris were more common.

TABLE 2 Clinical characteristics of patients (N = 2 886).

Characteristics	Parameter†
FB in right bronchial tree, N (%)	1 669 (60.5)
FB in left bronchial tree,N (%)	783 (28.4)
FB in larynx and trachea, N (%)	171 (6.2)
Double lung, N (%)	74 (2.7)
FB at the carina, N (%)	63 (2.3)
Cases with FBs removed, N (%)	2 760 (95.6)
Operation time (min)	17 ± 5
Recovery time (min)	8 ± 2
Hospital stay (d)	2 ± 0.5

FB, foreign body.

†Parameters are presented as mean ± standard deviation.

Of the 2 886 patients, 66 (2.3%) children had hypoxemia (SpO_2 < 90%) during the operation and recovered (SpO_2 ≥ 95%) within 30 s after increasing the oxygen concentration and providing manually assisted ventilation. Nineteen (0.66%) children developed laryngospasm after removal of the rigid bronchoscope, which improved with deeper anesthesia, less stimulation, pure oxygen inhalation and jaw rising. Furthermore, 206 (7.1%) children developed pneumonia after surgery and were treated with antibiotics, and 16 (0.55%) children had laryngeal and subglottic edema and were treated with inhalation of atomized glucocorticoid mixed with oxygen. No laryngeal nerve injury, vocal cord paralysis or tracheobronchial malacia was observed and postoperative tracheotomy was not required (Table 3). No significant acid-base imbalance and accumulation of carbon dioxide were revealed by blood gas analysis. There were no deaths during hospitalization or follow-up in this series. The average operation time was 17 ± 5 min and the clinical duration of action of rocuronium was 20–30 min. No case of prolonged neuromuscular block was found. The average length of hospital stay was 2 days.

DISCUSSION

The present retrospective study indicates that intravenous introduction of propofol-remifentanil combined with rocuronium is a safe and effective choice for anesthesia for FBA removal under pressure-control ventilation.

TABLE 3 Peri-interventional complications

Perioperative adverse events	N (%)
Desaturation/Hypoxemia	66 (2.4)
Laryngospasm	19 (0.6)
Intraoperative irritating cough,	3 (0.1)
Pneumothora	0
Tracheal perforation	0
Intraoperative body movement	76 (2.6)
Dynamic	0
Laryngeal and glottal swollen	15 (0.5)
Pneumonia	206 (7.1)
Death	0

Although the use of rigid bronchoscopy has achieved favorable results in many case series, there are still high risks associated with airway obstruction caused by FBA and serious complications such as hypoxemia, even respiratory and cardiac arrest which can lead to death.[9] The prognosis of FBA in children is dependent on the severity of respiratory distress, depth and location of FBA and equipment used. In addition, appropriate anesthesia also plays an important role in reducing serious complications and mortality.[10]

It is a great challenge to maintain adequate ventilation when sharing the airway with the surgeon. General anesthesia is undoubtedly the best option for FBA removal. Some reports showed that propofol-remifentanil anesthesia with spontaneous breathing for FBA removal had a higher incidence of coughing, breath holding, body movement and delayed recovery.[5,11] We performed anesthesia with propofol-remifentanil combined with rocuronium, which is a muscle relaxant for FBA removal and achieved a good jaw relaxation and a lower incidence of complications caused by the stimulation of air manipulation, as mentioned above.

Rocuronium has a more rapid effect in children and infants than in adults and a shorter time of effect in children than in infants and adults. It can be antagonized within 15–20 min after administration at 0.3 mg/kg. Rocuronium is one of the fastest nondepolarizing muscle relaxants and has better heart safety, smaller hemodynamic effects and does not cause histamine release. The clinical duration of action of rocuronium observed in our study was 20–30 min, which covered the surgery time (17 ± 5 min) very well. Low doses of rocuronium will result in a less intense block at laryngeal adductors,[12] which makes it difficult for tracheal intubation. Thus it is recommended that the optimal dose of rocuronium for rapid sequence induction should be higher than 1 mg/kg.[13] Tracheal intubation is generally performed 90 s after rocuronium (0.3 mg/kg) administration and 60 s after succinylcholine (1.5 mg/kg) administration. General anesthesia with rocuronium

(0.45 mg/kg) in infants revealed good results such as effect time, satisfaction of intubation, and time of restoration,[14,15] and was suitable for short operation.[16] The achieved tracheal intubation time observed in our study was 90–120 s without applying topical lidocaine on the pharynx. The dose of rocuronium (0.45 mg/kg) used in our study was determined to ensure a short onset time that was sufficient for clinical duration time for surgery and to avoid prolonged muscle relaxation. Rocuronium combined with remifentanil hydrochloride can significantly reduce masseter muscle tension, laryngospasm and bronchospasm. In addition, remifentanil can prevent the withdrawal response associated with rocuronium injection.[17]

A retrospective review of 287 cases of rigid bronchoscopic FBA removal showed incidence rates of adverse events related to anesthesia and surgery were 0.7% and 7.6%, respectively.[10] The most common adverse event related to anesthesia was laryngospasm.[10] Laryngospasm can be affected by preoperative respiratory distress, degree of respiratory tract obstruction, depth of anesthesia and stress-related responses.[8,19] In the present series, the incidence of laryngospasm was 0.65% which was lower than that in the study by Tomaske et al.[10] We speculate that the low laryngospasm rate in our series may be due to the suitable depth of anesthesia controlled by propofol-remifentanil and reduction of stress response by the muscle relaxant technique (rocuronium). Furthermore, propofol can also reduce the laryngeal reaction to stimulation,[20] and remifentanil can relieve coughing.[21] Thus the combination of propofol and remifentanil is generally applied for anesthesia of airway endoscopy.[22-25]

It is important to ensure adequate ventilation and prevent hypoxemia during anesthesia for FBA removal. Discussion regarding the optimal method of ventilation (spontaneous or controlled) is still ongoing.[3,7,26] SpO_2 <90% was observed in 66 cases (2.3%) in our study which quickly recovered to 95% after returning the rigid bronchoscope to the trachea and applying manual assist control ventilation. The incidence of hypoxemia in our study was lower than rates reported by Liao et al and Chen et al who used inhalation of sevoflurane anesthesia with spontaneous breathing. [11,27] In addition, intravenous anesthesia can allow an adequate depth of anesthesia and avoid pollution of the operation room with anesthetics gas during inhalational anesthesia.

We used pressure-control ventilation to prevent fatigue of the respiratory muscle, which is usually caused by spontaneous breathing. An airway spasm can increase airway pressure, which decreases the tidal volume and subsequently leads to hypoxemia. Thus, the minimum ventilating pressure had to be determined to inhibit increased airway pressure before a shortage of oxygen supply occurred. The controlled minimum ventilating pressure can also prevent or reduce possible air entrapment distal to the tracheal obstruction, which may be caused by the ball valve effect when attempting to perform positive-pressure ventilation.

The accumulation of carbon dioxide was the common complications during rigid bronchoscopy in the study by Skoulakis et al.[28] However no significant accumulation of carbon dioxide was found in our study, which may be attributed to the high flow rate of oxygen (3 L/min) and positive-pressure ventilation.

It has been reported that the mortality rate of FBA is 0.8%–1%,[29,30] and mortality of rigid bronchoscopy is 0.42%.[31] However no deaths were observed in our case. We speculate that this finding is attributed to the lower incidence of adverse complications. The average hospital stay was 2 days in our series which was shorter than that in the study by Tomaske et al.[10] However, this discrepancy may be due to differences in medical policies and economic factors.

Children, who cannot fast for 6 h, such as during emergency situations, can be treated as a patient with a full-stomach. We can then perform steps of postoperative sedation and tracheal intubation with the ventilator until the time exceeds gastric emptying.

There are still some disadvantages that must be noted. The foreign body shift under positive-pressure ventilation prolonged the operative time in some cases. Furthermore, while venous blood gas analysis is sufficient for evaluating acid-base imbalance and the accumulation of carbon dioxide, arterial blood gas analyses are also needed during anesthesia. Further randomized controlled double-blind trials are warranted to optimize our anesthetic technique for FBA removal.

CONFLICT OF INTEREST

We have read and understood the policy of Pediatric Investigation on declaration of interests and declare no competing interests.

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