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Original Article

Modified Broncho-Cath ™ Right double-lumen tube adaptor improves the safety and effectiveness of pediatric tracheobronchial foreign body removal

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Abstract: This study will examine the safety and effectiveness of using a modified Broncho-Cath ™ Right double-lumen tube adapter in the removal of pediatric tracheobronchial foreign bodies. 40 cases of pediatric tracheobronchial foreign bodies were randomly divided into two groups (n = 20): a high-frequency ventilation group (group H) and a modified Broncho-Cath ™ Right adapter group (group B). Patients in group H were anesthetized with intravenous propofol, ketamine, and fentanyl for slow induction. High frequency jet ventilation was applied via nose catheter. Patients in group B were administered midazolam, fentanyl, propofol, and succinylcholine for fast induction. Laryngeal masks were inserted and connected to modified Broncho-Cath ™ Right adapters to provide intermittent positive pressure ventilation. Fiberoptic bronchoscopy was used to remove airway foreign bodies in both groups of patients. There were five cases of foreign bodies located in the trachea, 22 cases in the left main bronchus, and 13 cases in the right bronchus. Foreign bodies were removed in all cases in group B but only in 18 cases in group H by fiberoptic bronchoscopy. The remaining two patients in group H had foreign bodies removed by rigid bronchoscopy. Compared to those in group H, children in group B had higher success rate of bronchoscope insertion at first attempt and shorter procedure duration ($P<0.05$). The incidence of cough during the procedure, hypoxemia, hypotension or hypertension was also lower ($P<0.05$). In summary, we found that using laryngeal mask connected to modified Broncho-Cath ™ Right double-lumen tube adaptor improved the ventilation and safety in pediatric tracheobronchial foreign body removal.

Keywords: Anesthesia, pediatric, tracheobronchial foreign bodies

Introduction

Airway foreign body is a common pediatric emergency, often life-threatening for infants and young children [1, 2]. In recent years, with the development of respiratory endoscopy, fiberoptic bronchoscopy has been widely used to remove the foreign bodies [3-5]. The small airway lumen of children has to be shared by ventilation and bronchoscopy apparatus during the removal procedure, making anesthesia for such procedure very challenging. The preferred anesthesia method, the intravenous anesthesia under spontaneous breathing, is difficult to control. Another challenge for the removal operation is coughing during surgery, which increases the operational difficulty and the surgical risk. In the current study, we explored the use of modified Broncho-Cath ™ Right double-lumen tube adaptors in the fiberoptic bronchoscopy removal procedure to remove tracheobronchial foreign body in 40 infants and young children to seek a safer and more effective anesthesia and ventilation management.

Patients and methods

This study was approved by the institutional ethics committee of Shanghai Pulmonary Hospitals. Written consents were obtained from the parents or guardians of all patients.

General patient data

From March 2012 to July 2014, we performed removal of tracheobronchial foreign bodies in 40 children; 25 males and 15 females, aged 9

months to 8 years old and weighing 8 to 30 kg. Before removal, 12 children had varying degrees of difficulty breathing. Four children had severe hypoxia with severe airway obstruction. There were varying degrees of wheezing in 18 cases by stethoscope examination, including three cases of diffused wheezing on both sides. Five cases of atelectasis were also revealed by chest X-ray examination. Of the 40 cases, 26 cases were graded as American Society of Anesthesiology (ASA) grade II, 10 cases ASA grade III, and 4 cases ASA grade IV. The foreign bodies included watermelon seeds, sunflower seeds, peanuts and soybeans. 31 patients came to the hospital within 10 hours of airway foreign body inhalation, seven after one week and two after two months. Patients were randomly divided into two groups of 20 each (n = 20): a high-frequency ventilation group (group H) and a modified Broncho-Cath ™ Right adapter group (group B).

Anesthesia and bronchoscope operation

After withholding oral food and fluid (NPO) for four to six hours, all patients were administered intramuscular injection of atropine (0.02 mg/kg) or scopolamine (0.01 mg/kg) at 30 min before operation. Before entering the operation room, patients were given intramuscular ketamine (3~4 mg/kg). Once in the operation room, patients were given intravenous dexamethasone (0.3 mg/kg) and monitored for electrocardiography (ECG), blood oxygen saturation (SpO_2), and NBP. Oxygen was supplied through facial masks. Patients in group H were given nasal furosemide drops and intravenous propofol (2~3 mg/kg), ketamine (1~2 mg/kg) and fentanyl (2 ug/kg) for slow induction. After full throat topical anesthesia, a jet catheter (internal diameter 1.5 mm) is inserted through the nose into the airway. High frequency jet ventilation (frequency 60~120 beats/min, oxygen driving pressure 0.6~1.0 kg/cm, respiration ratio 1:1.5) was then applied. A fibreoptic bronchoscope (Olympus Corporation, Japan) was inserted orally to remove the foreign objects. During the removal operation additional ketamine (1~2 mg/kg) or propofol (1~2 mg/kg) was added to maintain anesthesia.

Patients in Group B were injected with midazolam (1 mg/kg), fentanyl (3~4 ug/kg), propofol (2~3 mg/kg), and succinylcholine (2 mg/kg) for fast induction. After laryngeal mask (size selected according to the weight of children: No. 1.5 for 8~10 kg, No. 2 for 10~20 kg, No. 2.5 for 20~30 kg) insertion, the adapter for the Broncho-Cath ™ Right double-lumen endobronchial catheter (Mallinckrodt Medical Corporation, Ireland) was connected. The fibreoptic bronchoscope was inserted through the opening at the top of the adapter. The tip of the adaptor had been enlarged to fit the size of the fiberoptic bronchoscope. Manual intermittent positive pressure ventilation (IPPV) was applied at 15 to 30 beats/min. During operation, additional propofol was used to maintain anesthesia, as additional succinylcholine to maintain muscle relaxation. For patients in both groups, bronchoscopic foreign body removal was performed by the same group of experienced surgeons.

After surgery, patients in group H were provided with nasal oxygen catheter, and if necessary, mask ventilation or endotracheal intubation assisted breathing, until regaining consciousness and unassisted breathing. Patients in group B were ventilated through laryngeal mask until recovery of unassisted breathing and normal swallowing reflex. Then the laryngeal mask was removed and patient airway secretions were cleared.

Data recording

For all patients, mean arterial pressure (MAP), heart rate (HR), and arterial blood gas analysis of oxygen (PaO_2) and carbon dioxide ($PaCO_2$) were recorded at before anesthesia induction (T_0), at bronchoscope insertion (T_1), at 2min after insertion (T_2), at 5min after insertion (T_3), at 10 min after insertion (T_4) and after withdrawal of bronchoscope (T_5). The rate of successful bronchoscope insertion at first attempt, duration of bronchoscopy procedure, and time to regain consciousness is compared between the two groups. The incidence of intraoperative cough, bronchospasm, laryngospasm, severe hypoxemia (SpO_2<85% or SpO_2<90% sustained for 30 s), hypercapnia, hypertension (blood pressure 20% higher than the baseline) or hypotension (blood pressure 20% lower than the baseline) were also recorded [6].

Statistical analysis

Statistical analysis was performed using SPSS13.0. Measurement data were expressed

Table 1. Patient general data

Group	Gender (M/F)	Age (year)	ASA (n, II/ III or IV)	Height (cm)	Weight (kg)	Foreign body in trachea (n)	Left bronchus (n)	Right bronchus(n)
H (n = 20)	13/7	5.3±2.7	14/6	102±8	17.3±3.6	3	10	7
B (n = 20)	12/8	5.0±2.4	12/8	100±9	16.9±3.0	2	12	6

Table 2. Patient vital signs

Parameters	Group	T_0	T_1	T_2	T_3	T_4	T_5
MAP (mmHg)	H	72±8	92±7	83±8	78±6	80±7	74±8
	B	70±9	73±6*	69±5*	76±7	77±8	75±6
HR (per minute)	H	130±9	142±11	122±10	135±8	132±9	128±5
	B	132±6	118±7#	120±9	122±6*	129±7	126±7
PaO_2 (mmHg)	H	71±8	162±9	135±12	122±10	155±9	90±5
	B	73±7	198±13*	226±10#	202±12#	190±12*	88±6
$PaCO_2$ (mmHg)	H	32.5±3.2	33.6±4.2	35.2±4.0	37.3±4.2	34.3±3.1	35.2±2.7
	B	34.8±3.5	32.3±3.7	34.6±3.1	33.6±4.5	33.8±2.9	35.4±2.0

*P<0.05, #P<0.01 compared with group H.

Table 3. Patient operation parameters

Group	Procedure time (min)	Awaking time (min)	Successful first insertion (n)	Cough (n)	Airway spasm (n)	Laryngeal edema (n)	Severe hypoxemia (n)	High or low blood pressure (n)
H	23.5±8.4	35±11	11	9	2	1	5	13
B	16.2±6.2*	33±12	19*	0*	1	0	1*	5*

*P<0.05 compared with group H.

as mean ± standard deviation ($\bar{x}$ ± sd) and compared with the paired t-test. Count data were compared with the Chi-square test. Statistical significance was defined as P<0.05.

Results

General patient data are summarized in **Table 1**. No significant difference in gender, age, ASA classification, height, weight, etc. was observed between the two groups (P>0.05). Out of a total of 40 cases, foreign body was located in the trachea in 5 cases, in the left bronchus in 22 cases, in the right bronchus in 13 cases. The distribution of the foreign bodies is similar in both groups (P>0.05).

All foreign bodies were successfully removed by fiberoptic bronchoscopy in the modified Broncho-Cath ™ Right adapter group (group B). In the high-frequency ventilation group (group H), fibreoptic bronchoscopy was successful in removing foreign body in 18 cases. The two patients in whom fibreoptic bronchoscopy failed had follow-up rigid bronchoscopy to remove airway foreign bodies. Patient vital data during operation are shown in **Table 2**. Compared to patients in group H, patients in group B had lower MAP (P<0.05 at T_1 and T_2), lower HR (P<0.05 at T_1 and T_3), and higher PaO_2 (P<0.05 at T_1, T_2, T_3 and T_4) during bronchoscopy operation. No difference was observed at before (T_0) and after (T_5) bronchoscopy operation. There is no significant difference in $PaCO_2$ between the two groups of children at any time point (P>0.05).

Although no difference was observed in incidence of airway spasm and postoperative laryngeal edema between the two groups (P>0.05, **Table 3**), children in group B had shorter bronchoscopy procedure duration and lower incidence of intraoperative cough, severe hypoxemia, hypotension or hypertension than those in group H (P<0.05). The rate of successful bronchoscope insertion at first attempt was also higher in group B (P<0.05).

Discussion

The incidence of airway foreign body in children is higher than in adults partially because the laryngeal reflex is not fully developed in infants

or young children. Most foreign bodies are plant seeds [7, 8]. In this study, more than half of the cases (55%) involved foreign bodies in the left bronchus, consistent with previous reports that most of pediatric bronchial foreign bodies occur on the left side [8].

Currently there are a variety of ventilation methods for pediatric airway foreign body removal operation. Compared with controlled breathing, unassisted voluntary breathing can lead to insufficient ventilation in patients at deep anesthesia. At light anesthesia, there are risks of sudden cough or body movement, and bronchospasm, which can be life-threatening in children [9, 10]. In a retrospective investigation of 1035 pediatric tracheobronchial foreign body cases during an 18-year period, Hasdiraz et al, found higher incidence of adverse reactions in children under the age of four with unassisted voluntary breathing undergoing fibreoptic bronchoscopy operation [11]. In our study, there were nine cases of cough and three cases of bronchospasm despite adequate topical throat and trachea anesthesia. These symptoms were resolved after deeper anesthesia.

Jet ventilation has been used in fibreoptic bronchoscopy surgery [12, 13]. The advantage is that jet ventilation catheter is inserted through the nose and is separated from the fiberoptic bronchoscope. In this way the ventilation can be kept continuously. But even a fine catheter still occupies the narrow airways of infants and young children, hindering surgical operation and ventilation. Another risk is that jet ventilation catheter is prone to be accidently moved out during the bronchoscopy procedure. During high-frequency jet ventilation, the expiratory time is reduced, leading to CO_2 retention and elevated positive end-expiratory pressure, increasing the risk of hypoxemia [14].

The most common adverse reaction in tracheobronchial foreign body removal operations is hypoxemia [15]. In our study, five patients in the high-frequency ventilation group (group H) had severe hypoxemia during operation. Condition for two patients was improved after clearing respiratory secretions and bleeding. The remaining three cases are resolved with manual ventilation after the termination of the operation. In group B, the use of modified Broncho-Cath ™ Right double-lumen endobronchial tube adapter afforded insertion of the bronchoscope through the top opening to ensure the maximum opening of the small airways of infants and young children. Fiberoptic bronchoscope entering airway through the laryngeal mask reduces the chance of airway and laryngeal injury caused by repetitive insertion. After surgery the continual ventilation through the laryngeal mask also helps reducing postoperative hypoxemia.

Although difficult to operate and prone to throat damage [16], compared to fibreoptic bronchoscopy, rigid bronchoscopy has better field of vision and stronger clamping force to remove large airway foreign body and life-threatening airway tumors more quickly and effectively [17, 18]. In our study, two patients in group H suffered repeated failure to remove tracheal foreign bodies by fibreoptic bronchoscopy due to the large sizes of the foreign bodies. Only rigid bronchoscopy succeeded in removing these large objects.

Good anesthesia and sedation can improve the success rate of airway foreign body removal [19]. Propofol has fast onset and short half-life. Moreover; propofol has significant bronchodilatory as well as anti-emetic effect [20]. Its pharmacokinetic characteristics are well suited for anesthesia during interventional airway bronchoscopy surgery. Succinylcholine is a short-effect depolarizing muscle relaxant, with a rapid onset and recovery time, effectively preventing adverse reactions of various airway surgeries. It is degraded by cholinesterase in vivo, independent of liver and kidney functions. Our results also showed that the use of succinylcholine in children does not increase postoperative recovery time.

Conclusion

In summary, our study showed that in pediatric tracheobronchial foreign body removal operations, the use of modified Broncho-Cath ™ Right double-lumen tube adapter and laryngeal mask ventilation, combined with intravenous anesthesia, can improve patient safety by increasing patient ventilation and decreasing operation time.

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Disclosure of conflict of interest

None.

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