Anesthesia for removal of inhaled foreign bodies in children

AMIT SOODAN MD, DILIP PAWAR MD AND RAJESHWARI SUBRAMANIUM MD

Department of Anaesthesiology, All India Institute of Medical Sciences, New Delhi, India

Summary

Background: Foreign body aspiration may be a life-threatening emergency in children requiring immediate bronchoscopy under general anesthesia. Both controlled and spontaneous ventilation techniques have been used during anesthesia for bronchoscopic foreign body removal. There is no prospective study in the literature comparing these two techniques. This prospective randomized clinical trial was undertaken to compare spontaneous and controlled ventilation during anesthesia for removal of inhaled foreign bodies in children.
Methods: Thirty-six children posted for rigid bronchoscopy for removal of airway foreign bodies over a period of 2 years and 2 months in our institution were studied. After induction with sleep dose of thiopentone or halothane, they were randomly allocated to one of the two groups. In group I, 17 children were ventilated after obtaining paralysis with suxamethonium. In group II, 19 children were breathing halothane spontaneously in 100% oxygen.
Results: All the patients in the spontaneous ventilation group had to be converted to assisted ventilation because of either desaturation or inadequate depth of anesthesia. There was a significantly higher incidence of coughing and bucking in the spontaneous ventilation group compared with the controlled ventilation group ($P = 0.0012$).
Conclusion: Use of controlled ventilation with muscle relaxants and inhalation anesthesia provides an even and adequate depth of anesthesia for rigid bronchoscopy.

Keywords: anesthesia; anesthetic technique: bronchoscopy; ventilation; foreign body aspiration

Introduction

The aspiration of a foreign body in a child is a life threatening accident. Early diagnosis and bronchoscopic removal of the foreign body would protect the child from serious morbidity and even mortality. In infants and children, removal of airway foreign

Correspondence to: Dilip Pawar, Department of Anaesthesia, All India Institute of Medical Sciences, New Delhi 110029, India (email: dkpawar@hotmail.com).

body is performed under general anesthesia and through a ventilating rigid bronchoscope. Anesthesia for rigid bronchoscopy is a challenging procedure for the anesthesiologist who must share the airway with the bronchoscopist and maintain adequate depth of anesthesia. It is often difficult to maintain adequate ventilation and oxygenation in these patients. During removal of foreign body in children, Fearson *et al.* (1), Chatterji *et al.* (2), Baraka (3), Kim *et al.* (4), Perrin *et al.* (5), and Ahmed (6)

maintained spontaneous respiration whereas Kosloske [7], Blazer *et al.* [8] and Puhakka *et al.* [9] controlled the ventilation. Although both spontaneous and controlled ventilation techniques have been used successfully by these workers, there is no way of knowing the superiority of one technique over the other, as there is no study comparing the two techniques in the literature. This prospective randomized clinical trial was performed to compare these two techniques, namely controlled ventilation using muscle relaxant and spontaneous ventilation with inhalational anesthesia for rigid bronchoscopy for removal of airway foreign bodies.

Methods

This study was conducted at the All India Institute of Medical Sciences, New Delhi from October 1998 to November 2000. After approval by our institutional ethics committee and obtaining informed consent of the parents, 36 consecutive children who presented for rigid bronchoscopy for suspected foreign body aspiration either as routine or emergency procedure were included in the study.

All the children were premedicated with atropine 0.01 mg kg^{-1} intravenously immediately prior to induction if intravenous access was present or otherwise after induction. Anesthesia was induced either by halothane inhalation by mask or by sleep dose of thiopentone. Vocal cords were sprayed with one puff (10 mg) of lidocaine 10% spray. After induction, the children were randomly allocated to one of the two groups, with the help of a computer generated random table. In group I the patient's respiration was controlled where as group II patients were breathing spontaneously. In group I, introduction of bronchoscope was facilitated by suxamethonium 1.5 mg kg^{-1} whereas in group II it was performed under deep halothane. The children were maintained on intermittent positive pressure ventilation (IPPV) with O_2, halothane 0.5% and intermittent doses of suxamethonium in group I and on spontaneous respiration with O_2 and halothane 1.5–3% in group II. The fresh gas flow varied from 5 to 10 l·min^{-1} and was titrated so as to allow adequate filling of the reservoir bag. The concentration of halothane delivered to the patient was titrated to the clinical parameters of adequate anesthesia. Depth of anesthesia was assessed clinically by hemodyanamic parameters (heart rate, blood pressure), lacrimation, sweating, pattern of respiration, movement, coughing and bucking and tone of abdominal recti muscles. The dial setting of the vaporizer and fresh gas flows were recorded.

Anesthesia was maintained through a 'T' piece connected to the side arm of the rigid bronchoscope (Storz, Germany). Whenever there was persistent hypoxemia (saturation <90% for >2 min) or inability to maintain adequate depth of anesthesia leading to difficulty with bronchoscopy in a particular technique, it was decided to interrupt the technique and institute measures to restore normoxemia. In the spontaneous ventilation group, the respiration was assisted. In the controlled ventilation group the proximal end of bronchoscope was sealed and adequate ventilation ensured.

All children were monitored continuously for heart rate (HR), electrocardiography (ECG), pulse oximetry (SpO_2), and endtidal carbon dioxide (P_ECO_2) and noninvasive blood pressure (NIBP) at 5 min intervals. A 20% change in the value of heart rate, systolic and diastolic blood pressures from the basal value was taken as a significant change. Arterial desaturation was defined as SpO_2 value less than 90%. The severity of desaturation was graded as mild (SpO_2: 80–90%; severity score 1), moderate (SpO_2: 70–79%; severity score 2), and severe (SpO_2 < 70%; severity score 3). Arterial blood gas (ABG) samples were taken immediately after induction and at the end of the procedure. Significant events (if any), duration of anesthesia and instrumentation, and laryngeal evaluation by the bronchoscopist and anesthesiologist at end of the procedure were recorded. Lidocaine 1.5 mg kg^{-1} was given intravenously to all patients at the end of the procedure to decrease the incidence of coughing in the postbronchoscopy period. The children were taken to the recovery room from the operating room after they achieved a Steward's recovery score [10] of five or more. The children were nursed after the procedure with humidified oxygen for 2 h. Postoperatively, heart rate, respiratory rate, SpO_2 and episodes of coughing were monitored up to 1 h after the procedure or as long as such care was needed.

Outcome variables studied in the present study were: (a) incidence of hypoxemia (duration and degree of episodes of desaturation), (b) depth of anesthesia judged clinically, (c) evidence of pushing

the foreign body deeper into the respiratory tree during controlled ventilation.

The qualitative data such as sex, number of patients with intraoperative changes in heart rate and blood pressure, number of episodes of desaturation and incidence of complications in both groups were compared using chi-square test or Fisher's exact test where appropriate. The quantitative data such as age, weight, severity score of desaturation, ABG results and induction and recovery times were compared using the Students t-test after determining the normal distribution of the data. The values were represented as mean ± SD. The results were considered significant if P-value was less than 0.05.

Results

The age, weight and sex distribution in the two groups were comparable. The foreign bodies were mostly organic in nature with history of aspiration varying from 1 day to 2 months. The location of the foreign bodies was in either of the bronchi, or both the bronchi or bronchi as well as trachea (Table 1). There was no statistically significant difference in the number of patients with change in heart rate, systolic blood pressure and diastolic blood pressure in the two groups.

There were a total of 26 episodes of desaturation in 17 patients in group I and 21 episodes of desaturation in 19 patients in group II, giving a value of 1.5 and 1.1 episodes of desaturation per patient in groups I and II, respectively. The break

Table 1
Removed foreign bodies

Foreign body	Number of patients	Group I	Group II
Type			
Organic	27	13	12
Inorganic	5	1	4
Location			
Right bronchus	16	7	9
Left bronchus	8	5	3
Trachea	4	1	3
Multiple sites	4	1	9
Duration			
<3 Days	13	4	9
>3 Days	23	13	10

Table showing the nature (organic or inorganic) and location of the foreign bodies removed and the duration of time for which these foreign bodies were in the respiratory tract in both groups.

Table 2
Severity of desaturation

Severity score	Group I	Group II
1 (Mild)*	11	10
2 (Moderate)**	5	3
3 (Severe)***	10	8

Table showing the number of patients with mild, moderate and severe desaturations in each group.
*Severity score 1 (mild desaturation): SpO_2 80–90%.
**Severity score 2 (moderate desaturation): SpO_2 70–80%.
***Severity score 3 (severe desaturation): SpO_2 < 70%.

down of the number of episodes of desaturation according to severity is given in Table 2. The means of severity scores in groups I and II were 1.5 and 1.1, respectively. The number of episodes of desaturation and the severity scores were comparable in both the groups. The episodes of desaturation in the spontaneous ventilation group were clinically associated with hypoventilation, breath holding or apnea whereas those in the controlled ventilation group were clinically associated with inability to ventilate because of gross leak at the proximal end and/or apnea when the surgeon was trying to remove or localize the foreign body in the airway.

All the patients breathing spontaneously had to be assisted to maintain adequate oxygen saturation. Two patients in the spontaneous ventilation group (group II) remained desaturated even after controlled ventilation throughout the procedure until the foreign body was removed from the airway. In these two patients, the respiration had to be assisted for a major duration of the procedure and later controlled. If we exclude these two patients from the spontaneous respiration group (group II), then the means of percentage time of procedure during which the patients remained desaturated in both groups were 3.5 ± 4.7% for group I and 5.2 ± 6.6% for group II. There was no statistically significant difference.

The complications seen in our study were intraoperative bucking and coughing, ventricular arrhythmia, laryngospasm, convulsion and postoperative laryngeal edema and severe cough (Table 3). Incidence of intraoperative coughing and bucking in spontaneous group was statistically highly significant ($P = 0.0012$). All other complications were equally distributed between the two groups. There was no clinical evidence of pushing the foreign body deeper into the respiratory

Table 3
Complications

Complications	Group I (n = 17)	Group II (n = 19)
Intraop coughing and bucking	1	12*
Ventricular arrhythmia	1	3
Laryngospasm	1	3
Convulsions	0	1
Postop laryngeal edema	5	4
Postop severe cough	5	2

The number of patients with different complications in both groups. *$P = 0.0012$.

tree reported by any of the bronchoscopists in our study. The ABG results showed that there was mild hypercarbia and acidosis both at the start and the end of procedure in all the patients. The ABG results were comparable between the two groups. The continuous endtidal carbon dioxide data could not be obtained in all cases due to leakage of the expired gases around the bronchoscope. The time taken for induction of anesthesia was significantly shorter in group I (4.4 ± 4.0 min) compared with group II (14.1 ± 3.0 min). Similarly, the recovery times were shorter in group I (9.1 ± 4.7 min) than in group II (22.4 ± 8.6 min). The differences in induction and recovery times were statistically significant ($P < 0.001$).

Discussion

The presence of foreign body in the respiratory tract is a serious and on occasion fatal condition requiring immediate intervention. For the removal of aspirated foreign bodies in children there is no substitute for a rigid ventilating bronchoscope. It provides a much higher quality image and larger channels for instrumentation. During rigid bronchoscopy it is often difficult to maintain adequate ventilation and oxygenation in these patients as pulmonary gas exchange is already deranged. It is difficult to maintain an adequate depth of anesthesia during the procedure, as there is a constant leak of anesthetic gases through the proximal end and around the bronchoscope.

Ahmed (6) studied the records of 58 children who underwent rigid bronchoscopy for inhaled foreign bodies. General anesthesia was employed and spontaneous respiration was maintained when possible. The author found that all children suffered from some respiratory embarrassment intraoperatively, although the report does not comment on the

number of patients who had impaired oxygenation. Perrin *et al*. (5) found that they had to assist respiration in spontaneously breathing patients undergoing rigid bronchoscopy because of prolonged apnea or oxygen desaturation. Baraka (3) used assisted ventilation in 63 children undergoing bronchoscopy for removal of inhaled foreign bodies. He assisted the ventilation by intermittent flushing of oxygen via the sidearm of bronchoscope, without occluding the head of bronchoscope. In our study, we were unable to maintain any of the patients purely on spontaneous respiration and had to assist the respiration in all patients belonging to spontaneous ventilation group.

Litman *et al*. (11) in a retrospective analysis of 18 years' data showed that 11 of 26 cases of spontaneous and 5 of 18 cases of assisted ventilation had to be changed to controlled ventilation. It is possible that spontaneous ventilation used at the outset was not sufficient to maintain normoxia or paralysis was required because patients were moving. When there was a change in ventilatory technique it was always a change from spontaneous or assisted to controlled and not vice versa. In our study the respiration of all the patients in the spontaneous group had to be assisted and in two of them, later controlled.

Kosloske (7), Blazer *et al*. (8) and Puhakka *et al*. (9) used controlled ventilation technique for removal of aspirated foreign bodies in children. They did not mention intraoperative problems because of positive pressure ventilation during bronchoscopy. In our study, in the controlled ventilation group patients, there was an even depth of anesthesia and there was no episode of the foreign body being dislodged or pushed distally during removal. It was possible to improve oxygenation by providing an effective seal.

All the previously published reports are retrospective data and have the inherent fault of incomplete information of a retrospective analysis. This is the first prospective randomized study comparing spontaneous and controlled ventilation techniques. In our study the episodes of poor oxygenation and desaturation were because of bucking and coughing or from periods of shallow breathing, apnea or breath holding in the spontaneous respiration group. In the controlled ventilation group it was due to inadequate ventilation because of leakage of gas mixture from the proximal end of the bronchoscope or from prolonged apnea when the surgeon was

attempting to localize or retrieve the foreign body from the airway. Assisting the respiration manually or sealing the proximal end of the bronchoscope improved oxygenation. The episodes of desaturation and their duration were comparable between the two groups after the respiration was assisted in group II. Had we not assisted the respiration, the duration of desaturation in these children would have been significantly longer. Pawar has demonstrated in puppies that during spontaneous respiration, the minute ventilation decreases by 50% and the lung compliance tends to be low (personal communication). This could be due to the increased resistance of the bronchoscope telescope system. The inadequate ventilation and inability to maintain oxygenation could be because of these changes in the pulmonary mechanics imposed by the introduction of bronchoscope and telescope during spontaneous breathing. During controlled ventilation, as the work of breathing is taken over by the anesthetist, the resistance is easily overcome and adequate volumes can be delivered.

Another cause of poor oxygenation could be inadequate depth of anesthesia, as evidenced by increased frequency of coughing and bucking. The leakage of anesthetic gases from the open end of the bronchoscope and around the bronchoscope combined with decreased ventilation leads to inadequate delivery of inhalational agent to maintain an even depth.

One of the reasons given by Woods *et al.* (12), Kim *et al.* (4), and Ahmed (6) for avoiding controlled ventilation during bronchoscopic removal of foreign bodies is the possible complication of forcing the foreign body further into the bronchial tree. Pawar (13) has given an account of four cases in which the foreign body was dislodged 14 times during removal in both spontaneous as well as controlled ventilation, but there was no incidence of the foreign body being pushed distally. In our study there was no incidence of the foreign body being pushed down the bronchial tree during removal in either of the groups. The risk of pushing down a foreign body by positive pressure ventilation seems to be overstated and unsubstantiated.

Attempts were made to maintain adequate depth of anesthesia in both groups. In the spontaneous ventilation group, it was done by increasing the dial setting of delivered halothane from 1.5 to 3% compared with 0.5% in the controlled ventilation group. There was even depth of anesthesia in the patients in the controlled ventilation group as evidenced by a lesser number of episodes of intraoperative coughing and bucking. This is because the patients were paralysed and constant positive pressure ventilation was provided throughout the procedure delivering adequate anesthetic gases in oxygen to the lungs of the patient.

Several complications are associated with rigid bronchoscopy such as coughing and bucking, pneumothorax, mediastinal and subcutaneous emphysema, laryngospasm, laryngeal edema, cardiac arrhythmia, cardiac arrest, convulsions and death (1–10, 13). These could be due to many reasons such as inadequate depth of anesthesia, hypoxia, inadequate ventilation and vagal stimulation. The complications reported by workers using controlled or spontaneous ventilation techniques are similar. In our study the complications in both the groups were comparable except for intraoperative coughing and bucking, which was worse in group II patients probably because of inadequate depth of anesthesia. In our study, the incidence of severe postoperative cough in the controlled ventilation group was higher although not statistically significant, in spite of the same dose of intravenous lidocaine administered as in the spontaneous ventilation group probably because of early recovery and awakening. During rigid bronchoscopy the airway is manipulated repeatedly leading to airway edema and irritation. As a result, coughing is very common afterwards. It can be prevented by application of local anesthetic on the airway mucosa or by intravenous administration of lidocaine. Coughing could not have been because of pain in these patients as rigid bronchoscopy is not a painful procedure.

Convulsions under anesthesia are a serious and rare complication and can be due to factors such as hypoxia, hypercarbia or metabolic and electrolyte disturbances. In our study, one child in the spontaneous respiration group had convulsions during bronchoscopy. This 18-month-old girl was cyanosed, gasping and in respiratory distress on arrival. She had altered consciuosness with flaccid limbs and low saturations (50%). She had severe hypercarbia [$PaCO_2$: 13 kPa (100 mmHg)] and mild acidosis (BE: −7.5). The convulsions were manifested in the lighter plane of anesthesia. The exact cause of convulsion in this patient cannot be ascribed to

any particular factor as she had hypoxia, hypercarbia, probable metabolic and electrolyte derangements. The lidocaine spray in to the cords might have contributed to the occurrence as its toxicity is manifested in the presence of metabolic disorders (14). It is very unlikely that the anesthetic technique contributed to the occurrence of seizures in this case.

The number of patients required to identify significant incidence of various complications in any technique is high. The number of patients studied and reported by different workers is small. That is why it is difficult to make definite remarks on the contribution of any particular technique to the incidence of complications. However, most of the complications of bronchoscopy reported are due to inadequate depth of anesthesia. In spontaneously breathing patients, the depth of anesthesia has been shown to be inadequate and uneven compared with those on controlled ventilation.

From this study, we conclude that it is not possible to maintain an adequate depth of anesthesia with spontaneous respiration during rigid bronchoscopy for removal of inhaled foreign body in children and that respiration needs to be assisted. The use of controlled ventilation with muscle relaxants and inhalational anesthesia provides an even and adequate depth of anesthesia for rigid bronchoscopy. Considering the considerable morbidity and mortality associated with these procedures, they should not be taken lightly. We recommend routine use of controlled ventilation for bronchoscopy for the removal of inhaled foreign bodies.

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