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ORIGINAL ARTICLE

Foreign Body Aspiration in Pediatric Airway: A Clinical Study

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Abstract Immediate removal of foreign body (FB) can minimize the rate of complications. In the present study, we evaluated different types of foreign bodies, presenting clinical features amongst the children and their site of impaction. We also evaluated the anesthetic considerations during ventilation of pediatric airway in such Foreign body aspiration (FBA) patients. A retrospective study, for which prior Institutional Research Committee approval was taken, was conducted in 50 patients admitted in a tertiary care health centre. Relevant history regarding each patient's presenting symptoms or symptoms prior to hospitalization were recorded with special focus on interval between inhalation of foreign body and food intake. Each patient was examined for the nature and site of the foreign body. Appropriate method of ventilation for each case was discussed with the anesthesiologist before hand. Results of both therapeutic and diagnostic bronchoscopy were detailed. Majority of patients with foreign body aspiration (44%) were male children, between 1 and 3 years of age. The clinical features were mainly cough, respiratory distress and wheeze. Organic FB (73.9%) were the most common type of foreign body found. Right bronchus (64%) was the most common site of aspiration followed by left bronchus (24%). Jet ventilation was used in all the children, and duration of the rigid bronchoscopy was less than 15 min in majority of the cases. FBA are still dreaded as one of the leading causes of morbidity and mortality in infants and children that can be prevented by early diagnosis and management.

Keywords Pediatric age group · Foreign body aspiration · Airway problems · Peri-operative management

Introduction

Foreign body aspiration (FBA) is one of the leading cause of disease burden and fatality during childhood in our country and the exact number of deaths due to FBA is not known accurately [1]. The children aged between 0 and 3 constitute more than 75% of the FBA cases [2, 3]. Most Foreign Body (FB) do not cause severe symptoms unless they are present in the bronchus for long time in which case it causes secondary infections and pneumonia. FB that passes through the larynx usually ends up in one of the bronchi and seldom causes life threatening hypoxia. Tracheobronchial FBA can lead to fatal acute respiratory failure, when it causes near complete occlusion at the tracheal level. While a large FB can cause a sudden death by occluding the respiratory tract completely, a small foreign object may also result in death by causing first laryngospasm and then hypoxic crisis [4]. According to various studies, right main bronchus is the most common site, since the right main bronchus is wider than left and inter-bronchial septum projects towards left [5].

FB can cause symptoms like coughing, difficulty in breathing and hoarse voice in the early period, along with complications like obstructive emphysema, empyema, lung abscess, bronchiectasis, pneumothorax, atelectasis in late period. The most common objects to be aspirated are peanuts, food, plastic, metal, popcorn, bone, fruits. In contrast to inorganic FB such as toy parts, pen caps, pins,

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organic FB are more inductive of inflammatory reactions, and symptoms of fever and pneumonia are observed more frequently [6]. Chest radiography, Computed Tomography and rigid bronchoscopy are commonly used in the diagnosis of FBA [7]. The gold standard for treatment of FBA is rigid bronchoscopy with forceps removal even though flexible bronchoscopy is quite useful in certain conditions such as subglottic stenosis, laryngeal edema which does not allow the passage of rigid bronchoscope. In such cases tracheostomy is made and flexible bronchoscope can be inserted through aperture of tracheostomy and FB can be retrieved [8]. However, in cases of failed rigid bronchoscopy, the surgical options available for retrieving the FB include tracheostomy, bronchotomy and thoracotomy [9, 10]. Aim of this study is to know clinical and radiological profile of children diagnosed to have FBA and their outcome. This study also concurrently analyses the various methods of ventilation in children with FB bronchus.

Methodology

The present study was conducted in Department of Otolaryngology and Head and Neck Surgery, of an established tertiary care hospital in Northern Punjab over a period of 1 year. A total of 50 symptomatic patients diagnosed with FBA, were included in the study. The decision to perform bronchoscopy was based on clinical history, signs and symptoms, radiological findings as well as physical examination. Rigid bronchoscopy was done under short general anesthesia (Fig. 1). Pre-operative pediatric consultation was done with administration of antibiotics, typically cephalosporins and shot of steroids before any intervention. Considering the emergency nature of this procedure in majority of cases Nil per oral status of the child could not be ensured and hence intra-venous (IV) metoclopramide and ondansetron were given prophylactically.

Peri-operative Management

During the assessment, we focus on the 3 W ("what, where, when") to determine what was aspirated, where the aspirated FB has lodged, and when the aspiration occurred. Goal of anaesthesia is to provide adequate oxygenation, ventilation and Rapid return of upper airway reflexes. After taking children in the O.T we attached basic monitor SpO_2, NIBP, ECG, $EtCO_2$. After securing good IV access, injectable atropine sulphate 0.02 mg/kg was administered to decrease secretions, and minimize the autonomic reflexes during airway instrumentation. All children were preoxygenated for 3 min with 100% oxygen to denitrogenate the lungs and to lower $PaCO_2$.

Children were induced with either ketamine hydrochloride 2 mg/kg IV or oxygen in sevoflurane 2–3% by face mask. For muscle relaxation succinyl choline 1.5 mg/kg was administered and topical lidocaine 3–4 mg/kg was sprayed in larynx and tracheobronchial tree to prevent laryngospasm. Once the child was apneic, the surgeon introduced an appropriate sized bronchoscope and intermittent positive pressure ventilation was continued through the side port of the bronchoscope. Anaesthesia was maintained with repeat dose of ketamine or by oxygen and sevoflurane. Succinyl chloride 0.25–0.5 mg/kg was repeated whenever necessary with atropine sulphate 0.02 mg/kg. A variety of ventilatory techniques can be used during rigid bronchoscopy, following hyperventilation with 100 percent Oxygen which can be delivered by insufflation at high flow rates (10–15 l/min) by apneic oxygenation without actually ventilating the patient.

Although satisfactory oxygenation can be achieved for long periods, apnea should not extend beyond 5 min because of carbon dioxide accumulation. Oxygen and anaesthetic gases can be delivered through the sidearm of the bronchoscope by intermittent ventilation. Ventilation is possible as long as eyepiece is in place, but must be interrupted whenever removal of FB or suctioning is

Fig. 1 Showing instrument set including rigid bronchoscopes of variable sizes, endoscope, optical forceps along with jet venturi system for ventilation during FB removal

performed. During long procedure, carbon dioxide accumulates and predisposes the patient to dysrhythmias, particularly in the presence of light anaesthesia. Intermittent hyperventilation lowers $PaCO_2$ and deepens the anaesthesia. High flows of fresh gases are needed to compensate for the leak around the bronchoscope. Following the removal of the FB, a check bronchoscopy was done to ensure full clearance of FB and impact site for trauma, bleeding and granulation. Inj. Dexamethasone (0.4–1 mg/kg) IV, humidified oxygen and bronchodilators were given prophylactically in all the cases and nebulized racemic epinephrine was given wherever necessary to prevent postoperative stridor and distress. Patient were monitored continuously by pulse oximetry and ECG. A chest X-ray was taken at 6–8 h post-bronchoscopy to assess lung expansion and exclude a pneumothorax and residual FB.

Results

Out of 50 patients, 34 (68%) were males and 16 (32%) females with male female ratio being 2:1. Most common age group involved was between 0 and 3 years (44%) followed by 3–6 years (22%) (Table 1). Only 5 patients were brought to the hospital within a day of FBA. Majority children presented to the hospital after 3 days of aspiration. The earliest time took by patient to reach the hospital was 4 h while the longest time taken was 15 days (Table 2).

The clinical features of these patients were mainly cough, respiratory distress, wheeze, fever, stridor, choking and cyanosis in decreasing order. Only 6% of aspirated FB patients are spot diagnosed on X-ray chest as they were radio-opaque. Majority of patients X-ray-Chest showed emphysema in 48%, atelectasis and pneumonitis in 18% cases and 32%cases has normal Xray-Chest findings. FB were located in the right bronchus of 32(64%) patients, the left bronchus of 12(24%) patients and the trachea of 6(13.04%) patients (Table 3). The time of rigid bronchoscopic procedure ranged from 5 to 50 min with 64% in less than 15 min of cases and 36% in more than 15 min (Table 4). Only in 3 cases tracheostomy was required and reasons for the same were FB of long duration or sharp subglottic FB, and FB larger than the glottic chink. There was no fatality or long-term complication because of the tracheostomies (Table 4). A very few no. of cases, namely 4, required ventilator support and were put on mechanical ventilation in pediatric ICU due to laryngeal edema or laryngeal spasm with or without accompanying bronchospasm (Table 4). The most common type of FB found was organic with peanuts being the commonest (48%). Others were almond, rajma, maize, walnuts. Amongst inorganic FB, plastic was seen as the most common FB followed by glass, pins, and LED bulb (Table 5).

Table 1 Gender and Age distribution of children who presented with a foreign body

	No. of cases	Percentage
Total	50	100
Gender		
Male	34	68
Female	16	32
Age group (years)		
0–3	22	44
3–6	11	22
6–9	9	18
> 10	8	16
Place of residence		
Urban	40	80
Rural	10	20

Discussion

FBA poses a significant health hazard in young children. In our study most common age of FB aspiration was seen between 1 and 3 years of age. This finding was in accordance with previous studies as well [11–13]. Further, more male children visited the emergency with a FB compared to females, which is also in concordance with the previous literature [8, 14–16]. Aspiration is most dreaded in male children between 1 and 4 years of age [17].In this period of age, the child is eager to explore the environmental objects and the ambulatory preschooler is often unobserved in the houses by parents. Aydogan et al. depicted that most common type of FB were organic; seeds were the most frequent organic foreign bodies followed by peanuts [17].We also observed that peanuts were the most common foreign bodies. This was in accordance with the results from previous studies where the prevalence ranged between 33 and 55% [18–21]. However, another study has reported prevalence as low as 4% [22]. This should however be contemplated cautiously depending upon the ease of availability of the peanuts and other seeds in different study areas.

We observed that most common symptoms following the aspirations were cough, followed by respiratory distress, and wheeze, similar to other studies [22, 23]. However, choking has also been labeled as one of the most common symptom of FBA [24]. Generally, clinical presentation of affected children may range from non-specific respiratory symptoms to respiratory failure associated with asphyxiation [25]. Difficulty in swallowing hard foodstuff along with poorly developed protective reflexes make children more vulnerable than adults to inhalation of FB

Table 2 Time lapse between foreign body aspiration and reaching the hospital

Duration (days)	No. of cases	Percentage
Total	50	100
< 1 day	5	10
1–2 days	17	34
3–7 days	20	40
> 7 days	8	16

Table 3 Clinical features of the children who presented with a foreign body

	No. of patients	Percentage
Total	50	100
Presenting symptoms*		
Cough	42	84
Choking	8	16
Fever	17	34
Respiratory distress	32	64
Stridor	14	28
Wheeze	30	60
Cyanosis	6	12
Site of lodgment		
Right bronchus	32	64
Left bronchus	12	24
Trachea	6	12
Radiological findings		
Emphysema	24	48
Opaque foreign body	3	6
Atelectasis	9	18
Pneumonitis	9	18
Normal	16	32

*Multiple responses

into respiratory passage [26]. In our study, emphysema was seen as the most common radiological finding, Most of the studies have reported unilateral emphysema, and atelectasis amongst the commonest findings [17, 27, 28]. Most frequent site of lodgment seen in our study was right bronchus (64%) followed by left bronchus (24%). This was in too in concordance with the previous studies, who found inhaled FB to be more common in right bronchus with a percentage ranging between 40 and 48% [17, 29]. There are some anatomical determinants that favor right bronchi, but Cohen S et al. depicted that the FB were equally distributed between the left and right bronchi of children [30]. Therefore, none of the bronchus can be prioritized during the exploration just on the basis of previous literature. In our study, one in ten children required a tracheostomy following bronchoscopy, as FB was present distally. Therefore, in such cases bronchoscopy was done through the tracheostome to retrieved the FB. Previous studies have however depicted lower incidence of tracheostomy following bronchoscopy (2.6%) [28]. We lost one patient on second postoperative day of bronchoscopic FB removal, due to cardiopulmonary arrest precipitated by pneumothorax. Foltran et al. also reported similar incidence of cardiac arrest in (2.1%) patients while management of FB [31].

There are some anesthetic considerations that should also be discussed during the management of FB. We summarize the type of anesthesia that can be used during FB retrieval in Box 1. During induction of anaesthesia, patient should be kept calm and quiet as there are chances of displacement and migration of inhaled FB. But it is not advisable to give sedative pre-medication to avoid suppressing the respiratory drive. In most of the studies, smooth mask inhaled induction or I.V induction with spontaneous ventilation were used [32]. Cautious I.V. induction plus muscle relaxant with jet ventilation makes the introduction of endoscope easier as there is total muscle relaxation, which avoids airway trauma resulting from coughing and resistance. Intermittent jets of oxygen are used to ventilate the patients undergoing bronchoscopy, as it avoids hypoxemia in non-obstructed lung [33]. This is achieved with either a venturi system attached to the head of the bronchoscope or directly by administering oxygen via the side arm of the bronchoscope. Oxygen flushing via the side arm of the bronchoscope is simple and provides higher concentration of oxygen. Proximally located FB which require shorter procedure time, may be handled by spontaneous ventilation after introducing bronchoscopes. Anaesthesia for bronchoscopy with intermittent succinyl choline has been used successfully by number of investigators [34]. The use of succinyl choline keeps the patient totally quiet during the procedure; the bronchial caliber does not vary, and permits easy introduction of endoscope for removal of FB. Sometimes FB once gripped may be too large to be withdrawn through the lumen. It is not an infrequent complication to lose the FB from the forceps during the removal which commonly occur at subglottic region, if the muscle relaxation is not adequate which is known to occur often with spontaneous ventilation and maintenance by halothane. The major disadvantage of spontaneous ventilation techniques, with halothane as primary anaesthetic agent is, it requires higher concentrations of halothane to obliterate airway reflexes which may cause decreased myocardial contractility. This can be overcome by using I.V. or topical lidocaine with low concentration of halothane. This problem is not reported with apnoeic controlled ventilation techniques. Positive pressure ventilation avoides hypoxaemia and also improves oxygenation through avoidance of atelectasis but at times leads to

Table 4 Intervention characteristics used for the retrieval of the foreign body

	No. of patients	Percentage
Total	50	100
Type of ventilation		
Jet ventilation	50	100
Duration of rigid bronchoscopy		
5–15 min	32	64
> 15 min	18	36
Reason for Tracheostomy		
Foreign body bigger than glottic chink	1	2
Distal foreign body	2	4
Reasons for mechanical ventilation		
Laryngeal spasm	2	4
Laryngeal edema	2	4

Table 5 Types of FB retrieved on bronchoscopy

Type of foreign body	No. of cases (*n*)	Percentage
Total	50	100
Organic	39	78
Peanuts	24	48
Almond	7	14
Walnut	2	4
Rajma seed	2	4
Maize seed	2	4
Fruit seed	1	2
Fish bone	1	2
Inorganic	14	28
Plastic	11	22
Glass	1	2
LED bulb	1	2
Pin	1	2

overdistension of the obstructed lung which can embarrass the cardiovascular system and has been known to cause rupture of the alveoli resulting in tension pneumothorax. This method is known to dislodge the FB peripherally and may cause failure to retrieve the FB so positive pressure ventilation should be avoided during induction for the fear of converting proximal partial obstruction to a complete one. Severe cardiovascular embarrassment or even cardiac arrest may follow tracheobronchial manipulation and suction; this can be attributed to a combination of hypoxia and reflex vagal stimulation. Hypoxia aggravates vagal responses and increases the incidence of cardiac arrhythmias. Excessive suctioning during the procedure can markedly diminish oxygen concentration and also might induce atelectasis. Therefore suction must be applied for short periods of time which should be followed by lung inflation. Following the bronchoscopy subglottic edema could lead to respiratory distress, which can be prevented by preoperative steroids. Another advantage of this technique is recovery from anaesthesia is smoother and faster, whereas in spontaneous respiration techniques with halothane, recovery takes longer time and needs close observation and monitoring by an anesthesiologist to prevent hypoxia which is known to occur during that period [35].

Spontaneous ventilation has various advantages like lower risk compared to positive pressure ventilation of FB moving distally, that not only increases the difficulty of removal but also leads to ball-valve obstruction of the airway. It not only allows for continued ventilation during the entire procedure of FB removal but also ensures quick assessment of the adequacy of the airway after FB removal. Among the many disadvantages of spontaneous ventilation the most important is that the depth of anesthesia created to permit instrumentation into the airway decreases both the cardiac output of the patient and ventilation. It also increases the resistance to ventilation during instrumentation which further worsens the hypoventilation [36]. Spontaneous ventilation can be achieved by propofol which provides rapid recovery with good reflex suppression and when used for a short time it is non-cumulative and avoids inhalation of anaesthetic vapors by the bronchoscopist from the ventilating system when it is open during FB removal. Once the airway is secured it is combined with Narcotic analgesics like fentanyl (1 μg/kg).

On the other hand the many advantages of positive-pressure ventilation combined with a muscle-relaxant technique include immobilization of airway facilitating FB removal, balanced anaesthesia that decreases anaesthetic effects on cardiac output thus decreasing atelectasis, improving oxygenation and overcoming airway resistance when instrumentation is done [37].

Conclusion

To summarize**,** accidental inhalation or aspiration of both organic and non-organic FB continues to be a significant cause of childhood morbidity and mortality. Although prevention is best but once aspiration occurs early recognition and removal is a critical factor in the treatment of FB inhalation. Children should be referred to multi-disciplinary tertiary care centres for further evaluation and treatment. The most common symptoms encountered in routine practice are recurrent bouts of coughing, parent witnessed single episode of choking, acute dyspnea, and sudden onset of wheezing. Removal of the FB is routinely performed by rigid bronchoscopy, which is considered to

Box 1 Various Anaesthetic techniques for bronchoscopy during FB retrieval

Controlled ventilation	I.V. induction + muscle relaxant	Venturi attachment
		Inflation via side arm of bronchoscope
		Insufflation via a catheter in the trachea
		Insertion of a tube into the end of the bronchoscope intermittently
Spontaneous ventilation	I.V. induction	I.V. induction with thiopentone, or propofol or ketamine
		Maintenance with inhalation agent
	Inhalation induction	Halothane + Sevoflurane
		Maintenance with inhalation induction

be more reliable than flexible bronchoscopy. Failure of extraction and complications like tracheal or bronchial injury are rare. Although laryngeal FBs constitute a small proportion of all paediatric airway-FBs they can cause partial laryngeal obstruction that presents as hoarseness, aphonia, wheezing, and dyspnea. Treatment can be delayed due to difficulty in identifying laryngeal FBs during endoscopy, especially which are thin, made of plastic, or radiolucent FBs without X-ray findings. In such scenarios a witnessed choking event is the most important information in making an early diagnosis of FB aspiration.

For ventilation of pediatric airway during FB removal the choices of inhaled v/s IV induction, spontaneous v/s controlled ventilation, and inhaled v/s IV maintenance are case specific. Various different anesthetic techniques are equally effective at providing ventilation to children with FBA but no technique is optimal. Spontaneous ventilation is practiced routinely to reduce the chances of converting a partial proximal obstruction to a complete obstruction. On the other hand controlled ventilation with IV maintenance and paralysis provides suitable rigid bronchoscopy conditions and a satisfactory level of anesthesia. Therefore the anesthesiologist, bronchoscopist, and assistants need to be on the same page [38].

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