Indian J Thorac Cardiovasc Surg (April–June 2014) 30(2):140–146
DOI 10.1007/s12055-014-0279-8

ORIGINAL ARTICLE

Rigid bronchoscopic extraction of radiolucent foreign bodies in children: outcomes of early intervention

Yasser Shaban Mubarak · Ahmed Hasanein Mohamed · Yasser Ali Kamal

Received: 28 November 2013 / Revised: 28 January 2014 / Accepted: 4 February 2014 / Published online: 12 April 2014

Abstract
Objective The purpose of this study was to evaluate the role of rigid bronchoscopy in diagnosis and treatment of aspirated radiolucent foreign body (FB) in children.
Patients and method The study was conducted on 150 children with clinical suspicion of radiolucent tracheobronchial FB aspiration, between January 2011 and September 2013. There were 103 (68.7 %) boys and 47 (31.3 %) girls, with a male-to-female ratio of 2.1:1; their age ranged from 4 to 36 months. Removal of aspirated FB was performed under general anesthesia. Patients with favorable outcome were discharged within 24 h.
Results The most common clinical findings were cough (70 %), wheezing (54 %), diminished breath sound (64 %), fever (42 %), and dyspnea (27.3 %) and cyanosis (22.7 %). Rigid bronchoscopy for aspirated tracheobronchial FBs was positive in 95.3 %. The extracted FB was organic (peanuts and fruits) in 95.8 %, and the most common location for FB was the right main bronchus (49.6 %). The most sensitive clinical findings were cough (71.3 %), and the most specific findings were wheezing (85.7 %). Wheezing was a statistically significant predictor of the positive FB (odds ratio=7.6, CI=0.89 to 64.9). There was a statistically insignificant difference in demographic and clinical findings between the two positive groups of bronchial and tracheal FBs. The post-procedural complications were encountered in 7.3 % which included pneumonia (3.3 %), hypoxemia (2.7 %), and pneumothorax (1.3 %). The rate of complications was higher and statistically significant with intravenous anesthesia than with inhalation anesthesia (14.5 versus 3.1 %, respectively).
Conclusion Removal of radiolucent tracheobronchial FBs in children using rigid bronchoscopy can be performed safely with minimal risks and complications according to type, size, and location of FB. The index of suspicion is raised by careful history and physical examination.

Keywords Foreign body · Aspiration · Rigid bronchoscopy

Y. S. Mubarak (✉) · Y. A. Kamal
Department of Cardiothoracic Surgery, Minia University, Minia, Egypt
e-mail: yassermubarak21262@yahoo.com

A. H. Mohamed
Department of Anesthesiology and Intensive Care Unit, Minia University, Minia, Egypt

Introduction

Foreign body (FB) aspiration into the tracheobronchial tree is a frequent and serious cause of respiratory problems in childhood, especially among those younger than 3 years in whom 7 % of deaths are due to this event [1, 2]. Aspirated FBs should be extracted as soon as possible because a delay in diagnosis and extraction is always associated with increased complications. The incidence of complications increases after 24–48 h, making expeditious removal of the FB imperative [3, 4].

The clinical presentation and radiologic findings may be variable, can change with time, can be interpreted differently by different examiners, or may even be normal [5]. Chest radiography is usually the first diagnostic study ordered, with a reported sensitivity and specificity of 67 % to detect abnormalities consistent with a FB aspiration [6]. However, chest radiography is often inaccurate for the diagnosis of FBA when the object is radiolucent [7].

Rigid bronchoscopy (RB) is the standard treatment for removal of FBs in children [8]. It is the preferred technique for definitive diagnosis and extraction of inhaled FBs in

children because it is safe, simple, and effective in experienced hands [4, 9]. The purpose of this study was to determine the role of RB in the management of children with suspected radiolucent FB aspiration and evaluate outcomes of early intervention.

Patients and methods

Patients

This study was conducted on 150 children with clinical suspicion of tracheobronchial FB aspiration, who were hospitalized at the El-Minia University Hospital from 2011 to 2013. There were 103 (68.7 %) boys and 47 (31.3 %) girls, with a male-to-female ratio of 2.1:1. The mean age was 18.5± 8.3 months (range, 4–36 months). The indication for RB was based on a history and clinical examination suggestive of FB aspiration.

Anesthetic technique

Before induction of anesthesia, all children were premedicated with atropine (0.01 mg/kg) and dexamethasone (0.1 mg/kg). The type of general anesthesia was either total intravenous anesthesia (TIVA) or inhalation anesthesia with IV muscle relaxant. TIVA was induced with propofol (3–5 mg/kg), remifentanil (1 μg/kg), and succinyl choline (2 mg/kg). Anesthesia was maintained by infusion of propofol (100–150 μg/kg/min) and remifentanil (0.1 μg/kg/min), with bolus doses of succinyl choline (1 mg/kg) as clinically indicated.

Inhalation anesthesia was induced with sevoflurane 8 % in oxygen 8 L\min, then ketamine (2.5 mg/kg) and muscle relaxant (succinyl choline 1 mg/kg) was administered after the IV cannula was inserted. Anesthesia was maintained by inhalation of sevoflurane 4 % in oxygen 4 L\min.

Operative technique

Removal of tracheobronchial FB was performed under general anesthesia by a thoracic surgeon who is well trained in pediatric bronchoscopy. Monitoring was established with pulse oximetry (SpO_2/heart rate). After insertion of a rigid bronchoscope, the ventilator circuit was connected to the side port of the bronchoscope to sustain adequate ventilation and oxygenation. The ventilation was maintained by manual intermittent positive-pressure ventilation (MPPV).

The size of the pediatric rigid bronchoscopy used was according to age (3.5–4.5). FB was grasped by grasping forceps or using a dormia basket to avoid fragmentation of FBs. In cases of residual or remnant can not removed by bronchoscopy, either irrigation and suction or table down and chest percussion were performed.

(Figs. 1 and 2).

Postoperative care

After extraction of the FB, antibiotic and steroids were given to treat infection and laryngeal edema. All patients were followed up at least 6 h after the procedure by chest auscultation, temperature measurement, and chest X-ray. If patients had respiratory distress, they were kept in the intensive care unit (ICU).

Statistical analysis

The statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) software (version 16, SPSS, Inc, Chicago, IL, USA). Continuous and categorical variables were displayed as means±standard deviation (SD)

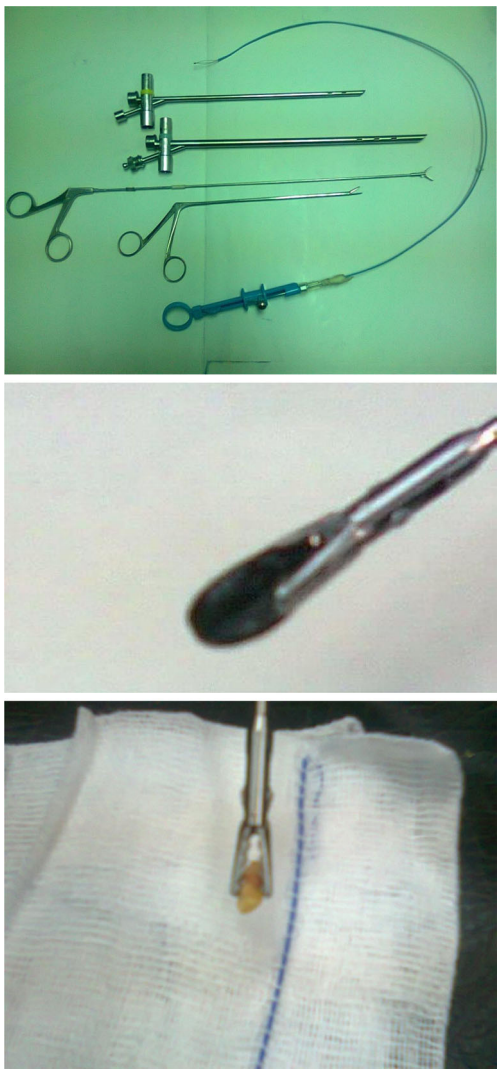

Fig. 1 Pediatric rigid bronchoscopy, alligator forceps, and dormia basket

Fig. 2 A radiolucent organic (food) tracheobronchial extracted by rigid bronchoscopy

and percentages, respectively. Student's *t* test was used to assess the differences between means. Differences between categorical variables were analyzed by chi-square test or Fisher's exact test. To estimate the diagnostic value of clinical manifestations of FB aspiration, sensitivity and specificity were calculated. Sensitivity was calculated according to the number of true positives divided by the number of true positives plus the number of false negatives. Specificity was calculated according to the number of true negatives divided by the number of true negatives plus the number of false positives. The odds ratio (OR) and its 95 % confidence interval (CI) were used to determine whether a particular exposure is a risk factor for presence of a tracheobronchial FB. Differences were considered statistically significant if $P < 0.05$.

Results

The demographic and clinical characteristics of the studied 150 children are shown in (Table 1). Cough was the most common presenting symptom (70 %), followed by wheezing (54 %) and dyspnea (27.3 %). A diminished breath sound was the most common presenting sign (64 %), followed by fever (42 %) and cyanosis (22.7 %). The time from event to RB was under 24 h in 66 %, 1–7 days in 14 %, and more than 7 days in 20 %. The inhalation anesthesia was used in 95 children (63.3 %), and intravenous anesthesia was used in 55 (36.7 %).

One hundred forty-three (95.3 %) procedures were positive for a FB, and 7 (4.7 %) were negative. The extracted FB was organic (food material) in 95.8 %—largely peanuts and fruits—and inorganic (plastic) in 4.2 %. The most common location for FB was the right bronchus (49.6 %) followed by the left bronchus (30.8 %) and trachea (19.6 %) (Table 2). The operative time ranged from 5 to 40 min, with mean of 15± 9.3 min.

The percentages of each clinical finding in both patients with positive FB and with negative FB were calculated and compared with each other to determine the diagnostic value of these findings (Table 3). The most sensitive clinical findings were cough (71.3 %) and diminished breath sounds (65 %), while the most specific findings were wheezing (85.7 %), cyanosis (85.7 %), and dyspnea (71.4 %). Wheezing was a statistically significant predictor of the positivity of rigid bronchoscopy as it has a significant high odds ratio which was 7.6 with confidence interval ranging from 0.89 to 64.9.

Among 143 children with positive FB aspiration extracted by rigid bronchoscopy, there were 115 (80.5 %) with bronchial FB and 28 (19.5 %) with tracheal FB. The percentages of demographic and clinical findings in both groups were calculated and compared (Table 4). The group of bronchial FB included 85 (74 %) boys and 20 (26 %) girls, and their mean age was 18.2±8.2 months. The clinical picture in the

Table 1 Demographic and clinical characteristics of 150 children underwent rigid bronchoscopic extraction of aspirated radiolucent foreign body

Variables	All children (n=150)
Age (months)	18.5±8.3 (range, 4–36)
Sex	
Male	103 (68.7 %)
Female	47 (31.3 %)
Clinical picture	
Cough	105 (70 %)
Wheezing	81 (54 %)
Dyspnea	41 (27.3 %)
Cyanosis	34 (22.7 %)
Diminished breath sounds	96 (64 %)
Fever	63 (42 %)
Time from event to bronchoscopy	
0–24 h	99 (66 %)
1–7 days	21 (14 %)
>7 days	30 (20 %)
Anesthetic technique	
Inhalation	95 (63.3 %)
Intravenous	55 (36.7 %)

Table 2 Type and site of foreign bodies in 143 children with positive bronchoscopy

Variables	Positive bronchoscopy (%) (n=143)
Type of FB	
Organic (food)	137 (95.8)
Inorganic (plastic)	6 (4.2)
Site of FB	
Right main bronchus	71 (49.6)
Left main bronchus	44 (30.8)
Tracheal	28 (19.6)

Table 3 Diagnostic value of different clinical findings in patients with positive foreign body

Clinical findings	FB+ patients (%) (n=143)	FB− patients (%) (n=7)	Sensitivity (%)	Specificity (%)	P value	Odds ratio (95 % CI)
Cough	102 (71.3)	3 (42.9)	71.3	57.1	0.10	3.3 (0.71–15.4)
Wheezing	80 (57.3)	1 (14.3)	57.3	85.7	0.03*	7.6 (0.89–64.9)
Dyspnea	39 (27.3)	2 (28.6)	27.3	71.4	0.94	0.93 (0.17–5)
Cyanosis	33 (23.1)	1 (14.3)	23.1	85.7	0.58	1.8 (0.20–15.4)
Diminished breath sounds	93 (65)	3 (42.9)	65	57.1	0.23	4.7 (0.89–25.6)
Fever	59 (41.3)	4 (57.1)	41.3	42.9	0.40	0.52 (0.11–2.4)

*Significant difference

bronchial group was cough in 80 (69.7 %), wheezing in 66 (57.4 %), dyspnea in 32 (27.8 %), cyanosis in 28 (24.3 %), diminished breath sounds in 75 (65.2 %), and fever in 46 (40 %). The time from event to bronchoscopy was within 24 h in 78 (67.8 %), 1–7 days in 14 (12.2 %), and more than 7 days in 23 (20 %).

The group of tracheal FB included 18 (64.2 %) boys and 10 (35.8 %) girls, and their mean age was 22±6.7 months. The clinical picture in the tracheal group was cough in 22 (78.6 %), wheezing in 14 (50 %), dyspnea in 7 (25 %), cyanosis in 5 (17.9 %), diminished breath sounds in 18 (64.2 %), and fever in 13 (46.9 %). The time from event to Bronchoscopy was within 24 h in 17 (60.7 %), 1–7 days in 7 (25 %), and more than 7 days in 4 (14.3 %).

The percentage of post-procedural complications in 150 children who underwent RB is shown in (Fig. 1). There was no complication in 139 (92.7 %), while complications were encountered in 11 (7.3 %) which included pneumonia in 5 (3.3 %), hypoxemia in 4 (2.7 %), and pneumothorax in 2 (1.3 %). The rate of complications was 7.8 % with bronchial FBs (n=9/115) and 7.1 % with tracheal FBs (n=2/28), with statistically insignificant difference between both groups (P >0.05). The rate of complications was 14.5 % with intravenous anesthesia (n=8/55) and 3.1 % with inhalation anesthesia (n=3/95), which was statistically significant (P=0.009) (Fig. 3).

Discussion

Aspiration of FB is a common problem in children, requiring prompt recognition and early treatment to minimize the potentially serious and sometimes fatal consequences [10]. Radiologic findings may vary from being diagnostic to totally unremarkable [11]. Most aspirated FBs are radiolucent. Hyper-aeration and/or atelectasis coupled with a history of FB aspiration should alert a physician to a retained FB [12].

The present study included 150 children with the suspicion of the aspiration of radiolucent tracheobronchial FBs. The male-to-female ratio was 2.1:1, and their age ranged from 4 months to 3 years. This finding is constant with other studies which identified that more than 80 % of cases of FB aspiration occur during early childhood, with a peak incidence between the ages of 10 and 24 months [9, 13]. Most cases of FB

Table 4 Comparison of characteristics of patients with tracheal foreign bodies or bronchial foreign bodies

Variables	Bronchial (n=115)	Tracheal (n=28)	P value
Age (months)	19.2±8.2	22±6.7	0.09
Sex			
Male	85 (74 %)	18 (64.2 %)	0.06
Female	20 (26 %)	10 (35.8 %)	
Clinical picture			
Cough	80 (69.7 %)	22 (78.6 %)	0.34
Wheezing	66 (57.4 %)	14 (50 %)	0.47
Dyspnea	32 (27.8 %)	7 (25 %)	0.76
Cyanosis	28 (24.3 %)	5 (17.9 %)	0.46
Diminished breath sounds	75 (65.2 %)	18 (64.2 %)	0.92
Fever	46 (40 %)	13 (46.9 %)	0.53
Time from event			
0–24 h	78 (67.8 %)	17 (60.7 %)	0.47
1–7 days	14 (12.2 %)	7 (25 %)	0.08
>7 days	23 (20 %)	4 (14.3 %)	0.48

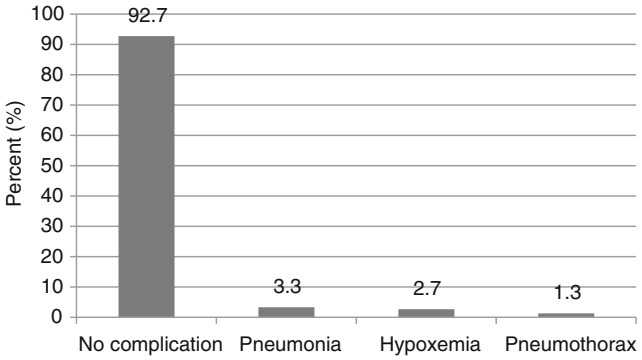

Fig. 3 Percentage of post-procedural complications in 150 children underwent rigid bronchoscopy

aspiration occur in males under 3 years of age which is probably due to the developmental characteristics in this age bracket as well as to the more adventurous and impulsive nature of young boys [14–16].

As in the present study, FB aspiration is usually suspected in children who have a strong history of possible aspiration. The first imaging modality often employed in the evaluation of suspected airway FB is the chest radiograph. Potential findings among patients with airway FBs include air trapping, opaque FB, peri-hilar infiltrates, atelectasis, and very important, a normal radiograph in approximately 9 to 30 % of children with a proven FB [5]. Furthermore, 90 % of airway FBs are radiolucent [17]. Therefore, it is important to establish what are the signs and symptoms that determine the need for a bronchoscopy when aspiration of a FB is suspected in childhood. In the present study, the most frequent clinical findings in cases with positive FB were cough (71.3 %), diminished breath sounds (65 %), and wheezing (57.3 %), which are similar to many other series [18–21].

In the present study, wheezing and cyanosis had the highest specificity (85.7 % for each finding). Moreover, wheezing was a statistically significant independent predictor of a positive result with RB. Therefore, the presence of wheezing as a presenting symptom should alert physicians for potential tracheobronchial radiolucent FB aspiration. Other studies in literature reported the diagnostic value of clinical symptoms and signs for both radiopaque and radiolucent FBs. Multiple studies have shown a high specificity of wheezing which ranged from 65.5 to 95.5 % [22–25], and other studies showed high specificity of cyanosis ranged from 98.1 to 100 % [5, 21].

In the present study, cough and diminished breath sounds had the highest sensitivity (71.3 and 65 %, respectively). The high sensitivity of cough was reported in multiple studies and ranged from 67.3 to 94.1 % [5, 21–25]. The absence of a patient history of acute choking/coughing or a witnessed aspiration episode constitutes a risk factor for diagnostic delay [23]. Other studies reported a sensitivity of 78–86 % and variable specificities of 26–81.3 % for diminished breath sounds [26, 27]. As pathologic auscultation in these studies included unilateral diminished breath sounds, wheezing, and stridor, this might result in lower diagnostic specificity.

In the present study, the time from event to bronchoscopy was within 24 h in 66 % and delayed up to 7 days in 20 %. Our high rate of FB in patients who were admitted within 24 h correlates with other reported series [24, 25, 28].

In the present study, rigid bronchoscopy was the procedure of choice for removal of radiolucent aspirated FBs in children. The rigid bronchoscope allows excellent access to the subglottic, allows for ventilation, allows the use of a rigid forceps to securely grasp the FB, and aids the management of mucosal hemorrhage [29–31]. In the present study, 95.3 % of children were positive for FB and 4.7 % were negative. According to the literature, the incidence of negative bronchoscopy rates may be as high as 19.5 % [22, 26, 31], and its positivity may reach 96.3 % [21]. It is better to perform some negative bronchoscopies than to leave a FB in the tracheobronchial tree. Therefore, bronchoscopy is mandatory for the definitive exclusion of FB aspiration in the presence of suspicious findings. Some authors suggest that the presence of at least two of the diagnostic criteria, including positive history, symptoms, PEFs, or radiological findings, is adequate to indicate a bronchoscopy [32].

In the present study, the extracted FBs were mostly organic (peanuts and fruits) in 95.8 % and inorganic in 4.2 %. In rural areas, parents leave their children to eat or try to eat or play in unclean surroundings with remnant of foods. Parents did not give attention to symptoms until their children became seriously ill because of cultural issues. In literature, FBs are mainly organic, but the type of FB depends on cultural, social and economic factors, and eating habits of different regions [24, 25, 33]. The nature of the FB aspirated is related to cultural habits, intellectual level, and socioeconomic situation of each country. Similar to our findings, peanuts and dried fruits predominate in another study from Egypt [34]. In the studies from the USA, the FBs most often aspirated are those of vegetable origin—peanuts predominating [35].

In the present study, the most common location for FB was the right bronchus which is followed by the left bronchus and trachea. This order is also the most commonly encountered in the literature [19, 24, 25]. Anatomically, the right bronchus, due to its greater verticality and larger diameter, favors the entry of a FB [26].

Although RB is a safe and useful technique for extracting FBs from the airway in pediatric patients, it is not without risks and complications [36]. In the present study, after RB, there was no complication in 139 (92.7 %), while rate of complications was 7.3 % in intervention beyond 7 days which included pneumonia in 3.3 %, hypoxemia in 2.7 %, and pneumothorax in 1.3 %. Pneumonia was diagnosed clinically and radiologically and treated with antibiotics according to culture and sensitivity of tracheal suction in consultation with the department of pediatric medicine. Pneumothorax was

diagnosed on follow-up chest X-ray and drained with a chest tube. Hypoxemia was treated by intubation and ventilation, corticosteroids, and bronchodilators. Our rate of complications is comparable with the 2–22 % [37–39] rate that is stated in published literature. As reported by other authors, pneumonia is the most frequent primary complication after RB in our series [15, 40]. Other frequent complications in literature include laryngeal edema and pneumothorax, but more serious complications such as tracheal tear, bronchial tear, hypoxia, and cardiorespiratory arrest can also occur. Fortunately, these complications remain exceptional, particularly for experienced pediatric bronchoscopy teams [26].

The study by Chen et al. [41] concluded that hypoxemia is the most frequent adverse event in rigid bronchoscopy for FB removal. The risk factors that correlated with intraoperative hypoxemia included patient age, type of FB, duration of surgical procedure, pneumonia before the procedure, and ventilation mode. Use of spontaneous ventilation increases the risk of hypoxemia, whereas manual jet ventilation decreases the incidence. This explains the reduced rate of postoperative hypoxemia in the present study as a manual bag ventilation was maintained via the bronchoscope.

In a majority of cases in the present series, general anesthesia was induced with inhalation agents in agreement with other authors who also preferred inhalation agents with or without spontaneous respiration [23, 42]. However, the choice of the induction technique is often based on the institution's protocol or on the anesthesiologist's preference. The inhalation group had a relatively better outcome, probably because the inhalation anesthetics are excreted earlier and faster than IV anesthetics [43].

In conclusion, a high index of clinical suspicion of radiolucent tracheobronchial FB aspiration should be considered in children younger than 3 years with normal findings on chest X-rays. There was no specific finding to indicate the presence of radiolucent tracheobronchial FB in this age; however, attention should be given to children who had wheezing at presentation along with a suggestive history of FB aspiration as it was a significant clinical predictor of the presence of tracheobronchial FB.

Acknowledgements Great thanks to Dr. Yasser Ali Kamal, assistant lecturer of cardiothoracic surgery for his effort in data collection and statistics.

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