Original Article

Clinico-radiological predictors of positive rigid bronchoscopy findings in children with suspected tracheobronchial foreign body aspiration

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Background: Tracheobronchial foreign body aspiration (TFBA) is common in young children and is associated with potentially significant morbidity, and sometimes mortality. Although rigid bronchoscopy (RB) is often needed for definitive diagnosis, it can be associated with intra-operative and long-term risks.

Methods: Hospital records of patients under 18 years of age who underwent RB for suspected TFBA between November 2010 and May 2016 were retrospectively reviewed. Data extracted include age, gender and date of TFBA. Specific pre-operative clinical and radiological findings were compared with findings at RB.

Results: Of 43 children admitted with suspected TFBA, 72% were aged under 3 years. 79.1% had a FB identified at RB. Clinical history of inhalation, auscultation and radiographic abnormalities [hyperinflation, collapse, suspected foreign body (FB)] were not significantly different for children with, compared to those without, TFBA at RB.

Conclusions: Although RB remains the definitive management for suspected TFBA, the potential risks and non-specific clinical and radiological findings mean other imaging techniques such as low dose multidetector computed tomography (MDCT) should be explored.

Keywords: Foreign body (FB); trachea; bronchus; imaging; radiography; clinical; bronchoscopy; paediatric

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Introduction

Tracheobronchial foreign body aspiration (TFBA) is a common paediatric emergency department presentation due to a tendency of infants and young children to place a range of objects in their mouths, as well as the paediatric airway anatomy (1,2). It can result in significant morbidity and mortality for children less than 3 years of age (3-6), including pneumonia, lung abscesses or bronchiectasis. A prompt and accurate diagnosis is therefore important in the management of this condition.

Children with suspected TFBA have variable clinical presentations, with symptoms such as cough, wheeze, noisy breathing or respiratory distress (7-10). Few children present with an actual witnessed episode of foreign body (FB) aspiration. Furthermore, physical examination findings and radiological investigations such as plain chest radiography (CXR) often do not provide additional diagnostic information (7,9,11,12).

Given the difficulty of accurately diagnosing children with suspected TFBA clinically, rigid bronchoscopy (RB) examination remains both the definitive diagnostic approach as well as a treatment modality if required (2,13). However,

Table 1 Patient demographics

Patient factor	N	Percentage %
Age		
0–3 years	31	72.1
>3 years	12	27.9
Median	25 months	–
Gender		
Male	27	63.0
Female	16	37.0
Comorbidities		
Asthma	3	7.0

this procedure is associated with significant risks such as airway trauma and pneumothorax, along with perioperative complications and potential long-term effects associated with general anaesthetic in children (6,14,15). Previously reported rates of negative RB findings greatly vary, ranging from 10 to 75% (2,3,12,16,17).

This is the first study to assess the diagnostic accuracy of various clinical and radiological findings in predicting the identification of TFBA at RB in the Australian paediatric population. Our aim was to identify clinical and radiological findings that could potentially identify children who were unlikely to have positive TFBA identification at RB to potentially reduce the rate of negative RB examination.

Methods

This was a single health service retrospective study of consecutive paediatric patients presenting with suspected lower respiratory tract FB from November 2010 to May 2016. Ethical approval was obtained from the Monash Health Human Research Ethics Low Risk Review Panel.

Inclusion criteria included paediatric patients 16 years or younger presenting with suspected TFBA who underwent RB as part of their management. All procedures were performed using RB with an optical telescope and high definition camera. Occasionally, flexible bronchoscopy was also performed to further exclude distal bronchial tree FB.

Information collected included age, gender, delay in presentation after suspected TFBA and date of hospital presentation. Symptoms of aspiration recorded included witnessed acute choking or coughing episodes, wheezing or clinical examination findings of reduced air entry or abnormal breath sounds, as well as CXR findings of suspected FB, collapse, consolidation or hyperinflation. Operative findings were also recorded. Surgical and anaesthetic complications were noted.

Blinded evaluation of preoperative clinical data (desaturation, wheeze, reduced air entry) and preoperative CXR were used to test diagnostic performance of individual and combined predictors of TFBA. Categorical data are presented in percentages while continuous data are presented as mean and median. The diagnostic accuracy [sensitivity, specificity, positive and negative predictive value (NPV)] of patient history, examination findings and radiological investigations was compared with the reference standard of bronchoscopic examination. Differences between positive and negative RB findings with regards to various factors were determined with Fisher's exact test. A P value of less than 0.05 was deemed statistically significant.

Results

Seventy-six children presented to Monash Health between November 2010 and May 2016, of which 43 met criteria for analysis. Patients were excluded if medical records or imaging results were not available (n=1), if the FB was located at or above the level of the glottis (n=3), if CXR images were not available (n=27), or if CXR showed inadequate inspiration (n=2). There were 27 males (63%) and 16 females (37%) (*Table 1*).

The median age was 25 months with 31 patients (72.1%) being less than 3 years of age. Median day of presentation after suspected inhalation was 0 days. Three patients had a history of diagnosed asthma.

Organic FBs were the most common (55.9% of all FBs), with the majority being nuts or pieces of vegetable (*Table 2*). Inorganic FBs represented 44.1% of all FBs, with the majority being pins. Only 7 FBs were radiopaque (20.6%). No FBs were identified in 9 children (20.9%) who underwent RB. Foreign bodies were most commonly found in the right main bronchus (32.3%) (*Table 3*).

There was no significant difference between the number of children with and without FB found on RB with regards to age (P=0.405), gender (P=0.706) and day of presentation after suspected inhalation (P=0.696) (*Table 4*).

Thirty-two children (74.4%) presented with a primary symptom of an acute onset coughing or choking episode, while 11 presented with other symptoms such as wheezing (*Table 4*). Neither of these symptoms was positively associated with the presence of a FB at RB (P=0.407).

Table 2 Types of inhaled foreign bodies

Foreign body type	N	Percentage %
No foreign body	9	20.9
Organic foreign body	19	44.2
Nuts	8	18.6
Seeds	3	7.0
Carrots	2	4.7
Other organic material	6	14.0
Inorganic foreign body	15	34.9
Pins (radio-opaque)	6	14.0
Stone (radio-opaque)	1	2.3
Plastic	6	14.0
Other inorganic material	2	4.7

Table 3 Location of inhaled foreign bodies

Anatomical location	N	Percentage
Trachea	8	18.6
Left main bronchus	11	25.6
Right main bronchus	14	32.6
Left intermediate bronchus	1	2.3

Table 4 Association of clinical findings with a foreign body found at RB

Patient factor	Likelihood of foreign body found at RB	Fisher's exact test (P value)
Age		0.405
0–3 years	23/31 (74.2%)	
>3 years	11/12 (91.7%)	
Gender		0.706
Male	22/27 (81.5%)	
Female	12/16 (75.0%)	
Day of presentation		0.696
Day of suspected inhalation	23/28 (82.1%)	
After day of suspected inhalation	11/15 (73.3%)	
Clinical symptoms		0.407
Coughing/choking episode	24/32 (75.0%)	
Others	10/11 (90.9%)	
Auscultation		0.294
Positive findings	26/29 (90.0%)	
Negative findings	8/14 (57.1%)	
Chest X-ray		1.000
Positive findings	24/30 (80.0%)	
Negative findings	10/13 (76.9%)	

Sixty-seven point four percent of children had abnormal chest auscultation findings of unilateral abnormal or reduced breath sounds. There was no significant difference between children with and without FB found on RB with regards to normal or non-diagnostic auscultation findings (P=0.294). The side of positive auscultation findings correlated 57.1% of the time with the side of TFBA finding on RB.

Moreover, no significant difference was found between those who had normal and abnormal CXR findings of suspected FB (P=0.6566), collapse (P=1.0000), consolidation (P=0.0948), hyperinflation (P=0.1710), or any abnormal CXR finding (P=1.000).

Thirty-five percent of children had an inspiratory and expiratory radiograph, and 16% had a lateral as well as an anteroposterior (AP) view. The positive predictive value (PPV) of auscultation findings was 0.90 with a 95% confidence interval of 0.77–0.96, which approached but did not reach statistical significance when compared with clinical and CXR findings (*Table 5*). No significant difference was found in specificity or negative predictive values (NPV) between clinical findings, chest auscultation and CXR findings, with a large 95% confidence interval for the sensitivity of each of the three predictive factors (*Table 5*). Hyperinflation (sensitivity 24%, specificity 100%) on CXR was found to be more specific than collapse or consolidation (sensitivity 26%, specificity 44%) for predicting the presence of a FB.

Of the 14 children with normal or non-diagnostic chest auscultation findings, 6 (42.9%) had normal lower airways on subsequent RB. The combination of an abnormal CXR and/or any clinical abnormality allowed better prediction of a FB (sensitivity 0.91 and specificity 0.22) but still a relatively high false positive rate (14.0%).

There were 2 complications (4.7%). One child developed a postoperative lower respiratory tract infection which resolved with antibiotics, whilst another had a

Table 5 Accuracy of predicting foreign bodies using presenting symptoms, chest auscultation and chest radiography

Clinico-radiological factor	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Clinical symptoms	0.71 (0.53–0.85)	0.11 (0.003–0.48)	0.75 (0.69–0.80)	0.09 (0.01–0.41)
Coughing/choking episode	0.03 (0.01–0.15)	1.00 (0.66–1.00)	1.00 (0.64–1.00)	0.21 (0.20–0.22)
Wheezing	0.26 (0.13–0.44)	0.89 (0.52–1.00)	0.90 (0.57–0.98)	0.24 (0.19–0.30)
Auscultation	0.76 (0.59–0.89)	0.67 (0.30–0.93)	0.90 (0.77–0.96)	0.43 (0.26–0.64)
CXR	0.71 (0.53–0.85)	0.33 (0.07–0.70)	0.80 (0.71–0.87)	0.23 (0.09–0.46)
Suspected FB	0.24 (0.11–0.41)	0.89 (0.52–1.00)	0.89 (0.53–0.98)	0.24 (0.19–0.29)
Collapse	0.18 (0.07–0.35)	0.78 (0.40–0.97)	0.75 (0.42–0.93)	0.20 (0.15–0.27)
Consolidation	0.09 (0.02–0.24)	0.67 (0.30–0.93)	0.50 (0.19–0.81)	0.16 (0.11–0.24)
Hyperinflation	0.24 (0.11–0.41)	1.00 (0.66–1.00)	1.00 (0.64–1.00)	0.26 (0.22–0.29)

PPV, positive predictive value; NPV, negative predictive value; CXR, chest radiography; FB, foreign body.

mucosal injury to the pyriform fossa which was managed conservatively. Unfortunately, one child was brought to hospital in cardiac arrest and, despite successful removal of the FB, died as a result of hypoxic brain injury.

Discussion

The prompt and accurate diagnosis of TFBA in children is important to prevent mortality or significant morbidity, including pneumonia, lung abscesses and bronchiectasis (3-6). However, if clinical and radiological findings are non-diagnostic, children with suspected TFBA often require RB examination (18,19).

Similar to previous studies, our data showed the majority of children presenting with TFBA to be less than three years of age (9,13,17). Moreover, the majority of FBs aspirated were food material (9,11). These may be explained by the developing neuromusculature and the lack of a complete set of molars for the coordination of pharyngeal swallow, respiratory, and oesophageal functions in children in failing to adequately protect their airways from foreign bodies (1,20), the calibre of the tracheobronchial anatomy in relation to the size of foreign bodies, and also the exploratory nature of children in this age group, particularly with placing objects into their mouths (13,17).

TFBA were most commonly located in the right main bronchus, consistent with the published literature, due to its more acute angle and wider calibre in relation to the rest of the tracheobronchial anatomy (11,21). This study demonstrated positive RB findings in 79.1%. The reported rates in the literature greatly vary, ranging from as low as 25% up to 90% (2,3,12,16,17). This may be due to the variable indications and referral processes for RB examinations in different paediatric hospitals.

Commonly reported clinical symptoms associated with TFBA are acute episodes of choking, coughing or wheezing, along with auscultation findings of unilateral abnormal or reduced breath sounds (3,19,22-24). These symptoms and clinical findings have often been shown to be the most sensitive and specific in the diagnosis of suspected TFBA (9,12,16). Although a large proportion of children (77.8%) in this study presented with symptoms of choking, cough or wheeze, there was no significant difference in the rates of positive RB findings between children with and without these symptoms. This may be due to the relatively small cohort in this study as well as the difficulty in establishing an accurate history retrospectively. The PPV of positive auscultation findings was higher than that of clinical and CXR findings but failed to reach statistical significance.

CXR findings associated with TFBA include unilateral hyperinflation, collapse or consolidation (7,11,12) (*Figure 1*). However, this study showed inconsistent radiographic technique in assessing TFBA with satisfactory inspiratory and expiratory films and did not identify significantly greater sensitivity of CXR findings compared to auscultation findings. This is consistent with data from the literature in which the majority of aspirated FBs are radiolucent (79.4% in this study), and most children present on the day of suspected aspiration when there are often no CXR findings of diagnostic value, with the first radiological findings being hyperinflation, which is reflected by its higher specificity in this study (3,9,19,25). Moreover, this study only found

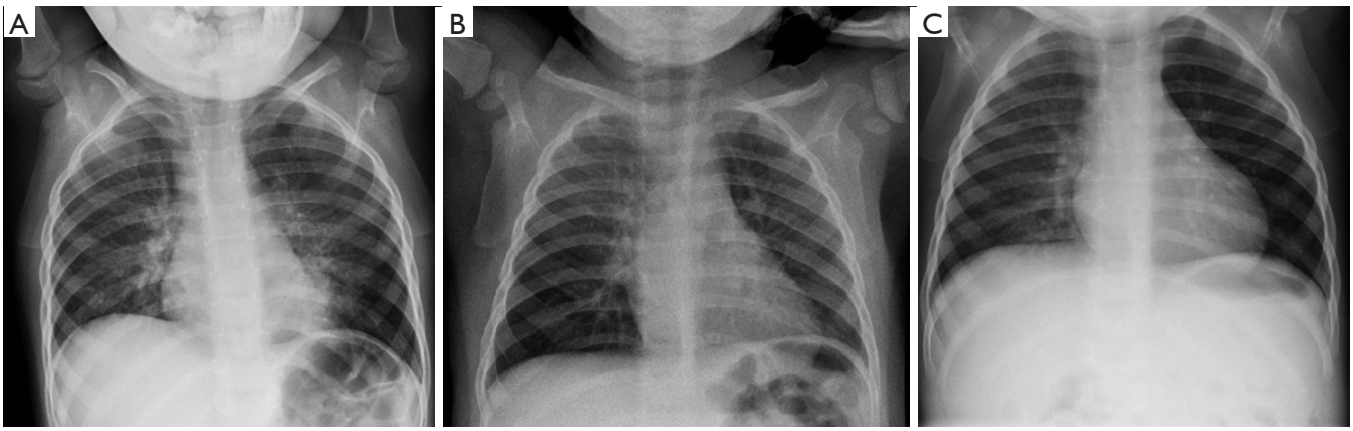

Figure 1 CXR showing: (A) left sided consolidation; (B) right upper lobe collapse; and (C) left sided hyperinflation. CXR, chest radiography.

a small proportion of radio-opaque FBs (20.6%), which is similar to previously reported values (9,11,17).

Limitations of this study include relatively small sample size, which may have resulted in a type II error in attempting to identify predictors of positive RB in the setting of suspected TBFA. Similar studies had shown conflicting results, with Heyer *et al.* concluding that witnessed aspiration, hyperinflation on CXR and white cell count to be statistically significant predictors of positive RB (12) while Divarci *et al.* had found that all positive clinical, examination and radiological findings were statistically significant predictors (26). Therefore, larger studies may be required to further assess clinico-radiological predictors of positive RB. The retrospective nature of our study also meant that radiographic technique was inconsistent between subjects with only an AP inspiratory view being consistently performed, and expiratory and lateral views in a minority of patients. This may have reduced the measured sensitivity and specificity of CXR. Finally, it was unclear what exact information the managing otolaryngologist used to decide how patients were selected for RB. Therefore, selection bias could not be excluded in our cohort due to patients who did not proceed to RB being excluded a priori from this study.

RB examination remains the gold standard for the definitive diagnosis and management of TFBA (2,13). RB is associated with rare but serious complications, including upper and lower airway trauma, laryngospasm, bronchospasm and pneumothorax (27-29). Hasdiraz *et al.* reports a rate of 4% for chest infections, 0.6% for airway trauma and 0.2% for pneumothorax out of 1,035 RB's performed (28). A recent review by Stahl *et al.* reported complication rates from RB ranging from less than 0.1 to 13% (14). Although general anaesthesia for RB is associated with low morbidity, significant adverse events such as pneumonia, respiratory failure or cardiovascular compromise can occur in the perioperative period (6,15). Moreover, there are conflicting results from recent studies regarding the possible long-term effects of general anaesthesia in early childhood, with some studies finding long-term effects such as neurocognitive impairment as well as behavioural and emotional consequences (30-32), while others finding no significant long-term effects (33).

In this study, 20.9% of children with clinically suspected TFBA had normal (negative) RB examinations. This is in keeping with the current literature, with negative bronchoscopy reported in 25% to 90% of cases (2,3,12,16,17). Although this study has shown a relatively high PPV for clinical, auscultation and CXR findings, this is often a difficult group to diagnose, and it is therefore important to balance the risks of RB and general anaesthetic with those associated with a missed diagnosis of FB aspiration in this subset of children with suspected TFBA.

Low dose multidetector computed tomography (MDCT) may be utilised as an alternative diagnostic tool for children with an unclear history of suspected TFBA without positive clinical or radiological findings; with studies showing this to be sensitive and specific in detecting aspirated FBs and hence reduce the likelihood of an unnecessary general anaesthetic and negative RB examination (34-37). *Figure 2* shows an example of a right sided segmental bronchiole FB found on MDCT. If the MDCT is suggestive of a FB then RB would be indicated, but if the MDCT is negative, the procedure might be avoidable in a normoxaemic child. Moreover, although traditional CT in children had

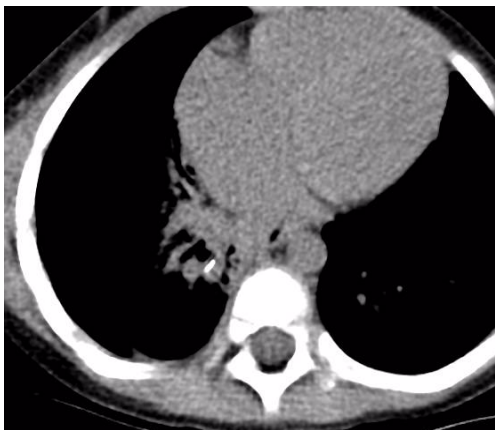

Figure 2 MDCT (axial views) showing right segmental bronchiole foreign body. MDCT, multidetector computed tomography.

been associated with breast, thyroid and haematological malignancy (38-40), use of child-sized lower kVp techniques and recent advances in ultra-low dose MDCT incorporating iterative reconstruction have significantly reduced radiation dosage for these investigations to as little as 1.5 mGy or less for chest CT (41), with conventional CXR, depending on the number of projections, delivering up to 0.9 mGy (42). Further prospective studies may be useful in assessing these investigations including technical challenges in obtaining technically adequate low-dose unsedated CT in young children, potential for overdiagnosis of airway abnormalities that do not represent FB, and logistical issues with performing and interpreting low dose paediatric CT studies after normal working hours (43).

Conclusions

TFBA is associated with potentially significant morbidity and mortality in children, therefore prompt and accurate diagnosis is often required. Children with non-specific history of aspiration and non-diagnostic clinical or radiological findings may undergo a negative RB examination under general anaesthetic. RB, even when negative, is costly and not without rare but serious risks, both in the perioperative period and longer term. It would therefore be beneficial to avoid unnecessary (negative) bronchoscopies. Newer techniques such as ultra-low dose MDCT may be useful in the management of these children, and prospective clinical trials, evaluating the clinical efficacy and cost of incorporation of low dose CT at defined points in the diagnostic algorithm, are warranted.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/ajo.2018.01.07). PP serves as an unpaid editorial board member of *Australian Journal of Otolaryngology*. JR serves as an unpaid editorial board member of *Australian Journal of Otolaryngology*. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Ethical approval was obtained from the Monash Health Human Research Ethics Low Risk Review Panel. Informed consent was waived due to the retrospective nature of the study.

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