

Original Research Article

Correlation between Virtual Bronchoscopy with Intraoperative Rigid Bronchoscopy Findings in Tracheobronchial Foreign Bodies

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ABSTRACT

Background: Foreign body aspiration is a persistent paediatric emergency, particularly in developing countries, and contributes substantially to illness and death. Removal of tracheobronchial foreign bodies is usually achieved through rigid bronchoscopy, a procedure associated with a mortality rate of up to 1.8%. This study aimed to evaluate the diagnostic accuracy of computed tomography-based virtual bronchoscopy (VB) by comparing its findings with those of rigid bronchoscopy (RB). The study also examined the utility of VB in children both with and without a clear history of aspiration.

Methods: Children presenting with either a suggestive history of aspiration or symptoms of airway obstruction underwent virtual bronchoscopy followed by intraoperative rigid bronchoscopy, after written informed consent was obtained.

Results: Thirty-six children underwent both VB and RB. VB identified a foreign body in 33 patients; RB confirmed the finding in 31 cases, while two were later diagnosed with mucus plugs. In three patients where VB showed no foreign body, RB revealed two plastic pen caps and one mucus plug. Overall, VB demonstrated a sensitivity of 93.94% (79.77-99.26%), a positive predictive value of 93.94% (87.39-97.20%), and an accuracy of 88.89% (73.94-96.89%).

Conclusion: Virtual bronchoscopy offers high sensitivity and positive predictive value in evaluating suspected tracheobronchial foreign bodies. Although not a substitute for RB, it is a valuable complementary tool that can guide management and reduce unnecessary invasive procedures.

Keywords: Tracheobronchial Foreign Body Aspiration, Virtual Bronchoscopy, Rigid Bronchoscopy.

INTRODUCTION

Tracheobronchial foreign body aspiration (TBFB) is a well-recognized paediatric emergency associated with considerable morbidity and, in some cases, mortality. Depending on severity and location, aspiration can lead to partial or complete airway obstruction, hypoxic brain damage, or, rarely, pulmonary haemorrhage.^[1] Despite improved awareness and emergency medical access, TBFB continues to pose diagnostic and therapeutic challenges due to varied presentations and the diversity of aspirated materials.

Young children are at greatest risk, owing to immature swallowing mechanisms, the absence of molars, and their tendency to explore objects orally. Since TBFB can mimic other respiratory conditions such as asthma or pneumonia, diagnosis is often delayed unless a high degree of suspicion is maintained.

The clinical and surgical significance of airway foreign bodies has been recognized for over a century, with Chevalier Jackson defining them as "an object or substance that is foreign to its location."^[2] Early identification and removal are essential to prevent complications such as

pneumonia, atelectasis, and chronic airway damage.

Tracheobronchial foreign body (TBFB) aspiration persists as a leading cause of death in children despite advancements in care. Diagnosis is frequently delayed because TBFB symptoms—particularly following an unwitnessed event—can easily mimic other medical conditions. Maintaining a high index of suspicion is crucial to prevent the complications resulting from delayed management. The clinical outcome and presentation of TBFB aspiration are multifaceted, dependent on the object's type and location, the degree of obstruction, the child's age, and the time from aspiration.^[3]

Imaging plays a pivotal role in diagnosis. While rigid bronchoscopy (RB) is both the gold standard and the definitive therapeutic intervention, it carries risks of complications and even mortality. Computed tomography (CT)-based virtual bronchoscopy (VB) has emerged as a non-invasive technique that allows three-dimensional evaluation of the airway and may help avoid unnecessary RB in cases where no foreign body is present.

This study aimed to compare VB findings with those of RB in paediatric TBFB cases, highlighting VB's diagnostic value and its potential to reduce reliance on invasive bronchoscopy.

MATERIALS & METHODS

This cross-sectional study was conducted at a tertiary care hospital in Karnataka from September 2022 to February 2024. Children admitted to the emergency department, paediatric ward, ENT ward, or paediatric intensive care unit with suspected tracheobronchial foreign body (TBFB) aspiration were considered for inclusion. A non-probability convenience sampling method was employed.

Inclusion Criteria

- Children with a suggestive history of foreign body aspiration
- Children presenting with features of lower airway obstruction, including sudden onset cough, respiratory distress, wheezing, haemoptysis, recurrent pneumonia, or reduced air entry on lung auscultation

Exclusion Criteria

- Patients with contraindications to rigid bronchoscopy, such as unstable cervical spine injury, temporomandibular joint

pathology, or unstable cardiovascular status

- Cases involving metallic foreign bodies or life-threatening emergencies requiring immediate bronchoscopic intervention

Imaging Protocol and Virtual Bronchoscopy Technique

All enrolled patients underwent detailed history taking and clinical examination followed by computed tomography (CT) of the chest with virtual bronchoscopy (VB). CT imaging was performed using a GE 16-slice multidetector CT scanner.

The patient was positioned supine on the CT table. Image acquisition was performed during a full inspiratory breath-hold to achieve optimal lung inflation and minimize motion artefacts. Thin-section axial images were obtained with a minimum slice thickness of 1.25 mm, which represents the lowest achievable slice thickness for bronchoscopy evaluation on the GE 16-slice system at our institution.

For image reconstruction, overlapping reconstructed sections were utilized to enhance spatial resolution and image quality. Additionally, thin-slice reconstructions of 0.625 mm were generated for multiplanar reformation (MPR), including coronal and sagittal planes, to facilitate detailed airway assessment. Three-dimensional rendering and virtual bronchoscopy images were created using GE workstation software. Virtual bronchoscopy readers were not blinded by the history.

Bronchoscopic Evaluation

Following CT and VB assessment, rigid bronchoscopy (RB) was performed under general anaesthesia in all patients. Rigid bronchoscopy served as both the diagnostic reference standard and the definitive therapeutic intervention for foreign body removal.

Data Collection

Clinical, radiological, and bronchoscopic findings were recorded using a structured proforma. Collected variables included demographic data, presenting symptoms, CT-VB findings, bronchoscopic findings, nature and location of foreign bodies, and procedural outcomes.

Sample Size

Using data from Bhat et al., who reported a sensitivity of 92.3% for VB in paediatric TBFB, the required sample size was calculated at 27, with 95% confidence interval and 5% margin of

error. A total of 36 children were ultimately included, after excluding six who could not undergo VB.^[4]

A considering proportion of tracheobronchial foreign body aspiration as 25%, the sample size is calculated by

$$n = \frac{Z^2(1-\alpha/2) * Se * (1 - Se)}{d^2 * p}$$

$$n = 27.3$$

The sample size was estimated using the expected sensitivity of virtual bronchoscopy for detecting tracheobronchial foreign bodies, based on the study by Bhat et al., which reported a sensitivity of 92.3%. Assuming a 95% confidence level and a precision of 5%, the minimum required sample size was calculated to be 27 participants. During the study period, 42 children with suspected tracheobronchial foreign body aspiration were evaluated, of whom 36 fulfilled the eligibility criteria and underwent virtual bronchoscopy. These 36 patients were included in the final analysis. The sample size estimation was performed prior to study initiation and was intended to ensure adequate assessment of the diagnostic performance of virtual bronchoscopy.

RESULTS

A total of 36 children, aged between 5 months and 14 years (median: 1.07 years), were included. The majority (38.9%) were aged 2.1–5 years. Boys comprised 69.7% of the cohort, and girls 30.3%. (Table 1)

A history of foreign body ingestion was recorded in 41.7% of cases. Organic objects accounted for 86.1% of foreign bodies,

primarily peanuts (50%), areca nuts (30.5%), and coconut pieces (5.6%). Inorganic materials (5.6%) included pen caps, while 8.3% of children had mucus plugs. The right bronchus was the most common site of lodgement (52.8%), followed by the left bronchus (38.9%) and trachea/carina (8.3%).

Clinical findings included noisy breathing in 63.9% of cases and chest retractions in 58.3%. Reduced air entry was noted on the right side in half of the patients and on the left side in 38.9%, with complete absence of breath sounds in 2.8%. (Table 2)

Of the 36 VB examinations, 33 (91.7%) suggested the presence of a foreign body. Among these, 31 were confirmed by RB, while 2 were mucus plugs. Three children were reported negative on VB; however, RB revealed two plastic pen caps and one mucus plug. Calculated diagnostic performance values for VB were:

- Sensitivity: 93.94% (79.77–99.26%)
- Specificity: 33.33% (0.84–90.57%)
- Positive Predictive Value: 93.94% (87.39–97.20%)
- Negative Predictive Value: 33.33% (5.83–80.16%)
- Accuracy: 88.89% (73.94–96.89%)

Variable	Categories	Number of Patients (N=36)	Percentage (%)
Age Group (in years)	< 1	9	25
	1.1-2.0	11	30.6
	2.1-5.0	14	38.9
	5.1-15.0	2	5.5
Gender	Male	23	63.9
	Female	13	36.1

Table 1: Characteristics of Study Population

Foreign Body		Number of Patients	Percentage
History of Foreign Body Ingestion	Present	15	41.7
	Absent	21	58.3
Type of Foreign Body	Organic	31	86.1
	Inorganic	2	5.6
	Others (Mucous Plug)	3	8.3
Area of Lodgement	Left Bronchus	14	38.9
	Right Bronchus	19	52.8

	Trachea or at the carina	3	8.3
Symptoms in Patients			
Noisy Breathing	Present	23	63.9
	Absent	13	36.1
Chest Retractions	Present	21	58.3
	Absent	15	41.7
Air Entry Status	Absent on left side	1	2.8
	Equal Bilaterally	3	8.3
	Reduced on left side	14	38.9
	Reduced on right side	18	50.0
Table 2: Characteristics of Foreign Body and Presented Symptoms in Study Population			

Correlation	Rigid Bronchoscopy			
		Present	Absent	Total
Virtual Bronchoscopy	Present	31	2	33
	Absent	2	1	3
	Total	33	3	36
Diagnostic Evaluation				
Statistic		Value	95% confidence interval	
Sensitivity		93.94%	79.77% to 99.26%	
Specificity		33.33%	0.84% to 90.57%	
Disease prevalence		91.67%	77.53% to 98.25%	
Positive Predictive Value		93.94%	87.39% to 97.20%	
Negative Predictive Value		33.33%	5.83% to 80.16%	
Accuracy		88.89%	73.94% to 96.89%	
Table 3: Correlation of Virtual Bronchoscopy with Rigid Bronchoscopy Findings among the study patients				

DISCUSSION

Tracheobronchial foreign body (TBFB) aspiration primarily affected younger children in our cohort, with 94.5% of cases falling into the 0–5-year age group, and the remaining 5.5% between 5 and 15 years. This aligns with findings by Ding et al.^[1] and Emily Guazzo et al.^[5] both of whom reported that the majority (over 80%) of airway foreign bodies are seen in children under 3 years of age, with a peak incidence between one and two years.

Our study showed a significant male preponderance with a male-to-female ratio of 1.77:1 (63.9% male, 36.1% female). This observation is supported by other studies, such as the one by Ding et al.^[1] which reported a higher male-to-female ratio of 2.6:1, and Vivek Samor et al.^[6] who also found males constituted the majority of cases (57.14%). This persistent trend across various studies suggests that the increased prevalence in males may be linked to their more impulsive behaviour.

Reflecting global trends, organic matter, particularly peanuts, constituted 50% of the organic foreign bodies found in our study. This observation underscores the findings of Vivek Samor et al.^[6] whose reported foreign bodies included peanuts (28.57%), needles (32.29%),

and plastic objects (21.43%). As Abhishek Jaswal et al.^[7] noted, food materials (seeds, beans) are the most common type in children under three years, while non-food items like pen caps are more prevalent in older children. The type of foreign body often reflects local dietary and socioeconomic conditions, with nuts remaining the most frequently aspirated item globally.

Regarding location, the right main bronchus was the most common site, harbouring 52.8% of foreign bodies, followed by the left main bronchus (38.9%), and the trachea/carina (8.3%). This distribution is comparable to the data from Vivek Samor et al.^[6] who also reported higher involvement of the right bronchial tree (39.3%) compared to the left (28.57%), and tracheal involvement in 21.43% of cases. This is primarily attributed to the anatomy of the right main bronchus, which is shorter, wider, and less deviated from the tracheal axis than the left.

The most common clinical sign in our study was decreased air entry (91%), followed by chest retractions, rhonchi, and stridor. This generally aligns with the symptoms observed by Vivek Samor et al.^[6] who reported cough (87.1%) and decreased breath sounds (71%) as the leading

presentations. Furthermore, a retrospective study by Shubha et al.^[8] emphasized the high predictive value of the classic clinical triad of cough, respiratory distress, and stridor.

Given the inherent risks of rigid bronchoscopy, we utilized Virtual Bronchoscopy (VB) as a diagnostic tool. Of the 36 suspected TBFB cases that underwent the procedure, 33 (91.7%) were reported positive for a foreign body. This diagnostic efficacy is supported by existing literature: Srivastava M et al.^[9] reported a 100% true positive rate for VB when compared to gold-standard bronchoscopy, and Adaletli I et al.^[10] stated that CT and VB correctly identified all cases of aspiration. Our study demonstrated a high diagnostic performance for VB, with a sensitivity of 93.94%, a positive predictive value of 93.94%, and an overall accuracy of 88.89%. This is consistent with findings by Bhat et al.^[4] (sensitivity 92.3%, PPV 92.3%) and Aishwarya Ullal et al.^[11] (PPV 97.3%). Two false-positive virtual bronchoscopy (VB) findings in our study were attributable to mucus plugs rather than true aspirated foreign bodies. These occurred in a 4-year-old child and a 1-year-8-month-old child, involving the left and right main bronchi, respectively. Mucus plugs can produce intraluminal filling defects that closely resemble foreign bodies on CT-based virtual bronchoscopic reconstructions, thereby posing a potential diagnostic challenge. As mucus plugs represent an endogenous airway pathology rather than an aspirated foreign body, they were not considered true foreign body-positive cases in the assessment of diagnostic accuracy. The occurrence of these false-positive findings highlights a recognized limitation of VB and underscores the importance of correlating imaging findings with the clinical presentation and bronchoscopic evaluation when establishing the diagnosis of foreign body aspiration. However, in two cases from our cohort, virtual bronchoscopy (VB) failed to identify the foreign body, while subsequent rigid bronchoscopy confirmed the presence of inorganic airway foreign bodies. Notably, both cases involved plastic pen caps with a central lumen. This finding highlights an important limitation of VB in the evaluation of hollow or air-containing foreign bodies. Because the internal lumen of such objects permits the passage of air and may exhibit attenuation characteristics similar to the surrounding airway, they can be difficult to distinguish on CT-based virtual reconstructions, leading to false-negative results. Similar observations have been reported in previous studies

evaluating VB for pediatric foreign body aspiration. Prajapati et al. reported a false-negative VB case despite an overall sensitivity of 88.88%, emphasizing that certain airway foreign bodies may remain undetected even with advanced imaging techniques.^[12] While most published studies have demonstrated high sensitivity and diagnostic accuracy of VB, false-negative findings have been described particularly with radiolucent, hollow, or low-density foreign bodies that mimic the normal tracheobronchial lumen. Therefore, although VB serves as a valuable non-invasive adjunct in the diagnostic workup of suspected foreign body aspiration, negative findings should be interpreted cautiously when clinical suspicion remains high. In such cases, rigid bronchoscopy continues to be the definitive diagnostic and therapeutic modality. Despite this limitation, our results indicate that a negative CT and VB, in the appropriate clinical context, may preclude the need for conventional rigid bronchoscopy in the definitive work-up, thereby potentially reducing procedure-related morbidity and mortality.

The present study is limited by its relatively small sample size, particularly the low number of patients without confirmed tracheobronchial foreign body aspiration. As a result, estimates of specificity and negative predictive value should be interpreted with caution, as they are based on a limited number of true-negative cases. Additionally, being a single-centre study, the findings may not be fully generalizable to other populations. Larger multicentre studies are warranted to further validate the diagnostic performance of virtual bronchoscopy in suspected foreign body aspiration.

CONCLUSION

Tracheobronchial foreign body aspiration in children remains a diagnostic challenge and requires vigilance in any child with acute or unexplained respiratory symptoms. Virtual bronchoscopy, when used alongside clinical suspicion, provides valuable diagnostic insight. While it cannot replace rigid bronchoscopy, VB demonstrates excellent sensitivity and positive predictive value, helping to guide management decisions and reduce unnecessary invasive procedures.

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