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Diagnostic Approaches to Pediatric Foreign Bodies: A Narrative Review

Diagnostic des corps étrangers intrabronchiques chez l'enfant : Mise au point

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ABSTRACT

Foreign body aspiration (FBA) is a common and potentially life-threatening pediatric emergency, predominantly affecting children aged 1 to 3 years. Establishing a timely diagnosis remains challenging due to the polymorphic clinical presentation and the limited individual sensitivity or specificity of conventional diagnostic investigations. A structured, evidence-based approach is paramount to prevent diagnostic delays, which can lead to severe long-term pulmonary sequelae such as atelectasis, recurrent pneumonia, and bronchiectasis. This review provides a comprehensive update on key diagnostic modalities,including clinical history, physical examination, and imaging, and introduces an updated decision-making algorithm to optimize the indications for rigid bronchoscopy, the gold standard for both diagnosis and therapeutic intervention.

Keywords : Bronchoscopy · Children · Diagnostic algorithm · Foreign body aspiration · Computed tomography (CT)

RÉSUMÉ

L'inhalation de corps étrangers (ICE) représente une urgence pédiatrique fréquente et potentiellement mortelle, touchant principalement les enfants âgés de 1 à 3 ans. Établir un diagnostic précoce reste un défi en raison d'une présentation clinique polymorphe et des performances limitées (sensibilité et spécificité) de chaque examen complémentaire conventionnel pris isolément. Une approche structurée, fondée sur des données probantes, est essentielle pour éviter les retards diagnostiques, ces derniers étant pourvoyeurs de séquelles pulmonaires chroniques graves telles que l'atélectasie, les pneumopathies récidivantes et les bronchectasies. Cette mise au point propose une revue exhaustive des principales modalités diagnostiques, incluant l'anamnèse, l'examen clinique et l'imagerie, et introduit un algorithme décisionnel actualisé afin d'optimiser les indications de la bronchoscopie rigide, le standard de référence (*gold standard*) tant sur le plan diagnostique que thérapeutique.

Mots clés : Bronchoscopie · Enfant · Algorithme diagnostique · Inhalation de corps étranger · Tomodensitométrie (TDM)

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INTRODUCTION

Foreign body aspiration (FBA) is one of the leading causes of accidental death in children under 5 years of age worldwide [1]. In Europe, it accounts for approximately 1% of pediatric accidental fatalities [1]. The vast majority of cases involve children aged between 1 and 3 years, a period characterized by intense oral exploration combined with neuromuscular immaturity of the swallowing mechanism [1,2].

The nature of aspirated foreign bodies varies by region: in the Maghreb and sub-Saharan Africa, plant seeds and pits predominate significantly (e.g., watermelon seeds, peanuts, olive pits), whereas in Western countries, plastic objects and processed food items are also frequently encountered [2,3].

The organic, vegetable nature of these foreign bodies worsens the prognosis due to an hygroscopic effect that promotes swelling and local inflammation [2].

Diagnosis remains a major clinical challenge: a typical choking crisis (penetration syndrome) may be absent in 20% to 40% of cases, standard chest radiographs are normal in 30% to 50% of radiolucent foreign body cases, and the median diagnostic delay often exceeds one week, significantly increasing the risk of secondary complications [1,3,4].

EPIDEMIOLOGICAL DATA AND RISK FACTORS

Several large-scale pediatric cohorts consistently demonstrate the following clinical patterns [1-5]:

Male predominance [1,4]: A sex ratio ranging from 1.5:1 to 2:1 across virtually all published studies.

Median age [2]: Typically between 2 and 3 years, with a peak incidence observed between 12 and 36 months.

Anatomical distribution [3,5]: The majority of foreign bodies lodge in the right main bronchus (50–60%), followed by the left main bronchus (30–35%), and less frequently in the trachea (5–10%).

Time to bronchoscopy: A median delay of 7 to 16 days between the aspiration event and bronchoscopy has been reported in North African series, highlighting a pervasive diagnostic latency [2,3].

Negative bronchoscopy rate [4,5]: Ranges from 20% to 25% when risk stratification protocols are not utilized, which justifies incorporating computed tomography (CT) imaging in equivocal cases.

These epidemiological trends have driven the development of clinical scoring systems designed to stratify patient risk and optimize the indications for bronchoscopy [2,5].

CLINICAL PRESENTATION

The Choking episode (Penetration Syndrome)

The choking episode, historically referred to as the penetration syndrome, is characterized by a sudden onset of paroxysmal coughing, choking, stridor, or chest wall indrawing, occasionally accompanied by cyanosis, typically occurring during routine activities such as eating or playing [1,3]. Although its sensitivity varies widely across cohorts (60–90%), its specificity remains low (24–35%). Consequently, the absence of a witnessed choking crisis cannot rule out a bronchial foreign body [1,5].

Clinical Presentation at Consultation

Symptoms at presentation depend heavily on both the anatomical location of the foreign body and the time elapsed since the aspiration event [3,4]:

Acute phase (< 24 hours): Predominantly features coughing, dyspnea, retractions, stridor, and unilateral wheezing [3].

Latent phase (days to weeks): Marked by a deceptive, asymptomatic period or a mild, residual chronic cough [1,4].

Chronic phase (> 1 month): Presents as recurrent or persistent lobar pneumonia, atelectasis, lung abscess, or bronchiectasis. These chronic presentations are frequently misdiagnosed as refractory asthma [5].

A recent prospective study highlighted that a cough (88%) and decreased breath sounds (58.9%) are the clinical features most strongly associated with a positive bronchoscopy [5].

Physical Examination

Pulmonary auscultation remains the cornerstone of the clinical evaluation. Asymmetrical auscultatory findings, specifically a unilateral decrease in breath sounds and/or localized wheezing, represent the most predictive physical signs of a positive bronchoscopy (sensitivity: 82.8%) [1,5]. However, a normal physical examination does not definitively exclude the diagnosis [1].

ANCILLARY INVESTIGATIONS

Standard Chest Radiography

An anteroposterior *(ou posteroanterior selon l'âge)* chest radiograph, performed during inspiration and, whenever feasible, expiration (or bilateral lateral decubitus views in uncooperative infants), remains the first-line imaging modality [2,3]. However, its diagnostic performance is inherently limited: **Sensitivity:** 50–70%; **Specificity:** 60–80% **Normal findings:** Observed in 30–50% of cases involving radiolucent foreign bodies (e.g., organic materials, plastics) [1,3].

The primary radiographic features include:

Direct visualization: Observed in only 15–20% of cases, restricted exclusively to radiopaque foreign bodies (e.g., metal, bones).

Unilateral obstructive emphysema: Manifesting as localized hyperlucency of a lung or lobe due to a ball-valve mechanism; this represents the most specific indirect radiographic sign.

Localized atelectasis or recurrent lobar pneumonia confined to the same anatomical territory.

Mediastinal shift: The mediastinum may appear centered or shifted contralateral to the side of the foreign body.

Comparing inspiratory and expiratory views exacerbates air trapping, thereby enhancing diagnostic sensitivity. When patient cooperation cannot be achieved, right and left lateral decubitus radiographs can successfully demonstrate a failure of the affected lung to collapse when dependent [2,4].

Low-Dose Computed Tomography (LDCT)

Thoracic computed tomography (CT) now plays an increasing role in the diagnostic algorithm, particularly in cases with a moderate clinical suspicion combined with normal or equivocal plain radiographs [1,4]. A 2024 meta-analysis encompassing 18 studies (4,178 patients) demonstrated that CT features a sensitivity of 99% (95% CI [97–100%]) and a specificity of 98% (95% CI [96–99%]) for diagnosing bronchial foreign bodies in children [1].

Furthermore, a recent retrospective study (2025, 165 children) compared two cohorts: immediate bronchoscopy versus pre-operative CT imaging [4]. The foreign body detection rate was significantly higher in the pre-operative CT cohort (93% vs. 77.9%), while the negative bronchoscopy rate was substantially reduced (7% vs. 22.1%)[4].

The implementation of low-dose CT (LDCT) protocols minimizes ionizing radiation exposure to levels equivalent to only a few standard radiographs, thereby mitigating safety concerns in clinical practice [1,4]. Additionally, virtual bronchoscopy (3D airway reconstruction) can be performed as a complementary diagnostic tool [1].

Nevertheless, CT scanning does not supplant rigid bronchoscopy in cases with a high clinical index of suspicion, as it remains a purely diagnostic modality with no therapeutic capability [1,2].

Advances in multi-detector CT software enable v**irtual bronchoscopy (VB),** a non-invasive, 3D internal rendering of the tracheobronchial tree. VB allows precise visualization of the airway lumen, accurate localization of radiolucent foreign bodies (such as organic seeds or plastic items), and assessment of distal mucosal changes without the risks associated with invasive endoscopy or general anesthesia.

A 2024 meta-analysis encompassing 18 studies (4,178 patients) demonstrated that CT/VB features a sensitivity of 99% (95% CI [97–100%]) and a specificity of 98% (95% CI [96–99%]) for diagnosing bronchial foreign bodies in children [1]. While VB cannot replace therapeutic rigid bronchoscopy, its high negative predictive value serves as a valuable gatekeeper to prevent unnecessary invasive procedures [1]. (Figure2)

Flexible Bronchoscopy

Flexible bronchoscopy is the most sensitive and specific endoscopic investigation following CT imaging, provided it is performed in an appropriate medical environment (such as an operating theater or a fully equipped resuscitation suite) [4,5]. Its primary indications include:

Cases with moderate suspicion lacking definitive clinical or radiographic signs [2].

Minimizing the rate of negative rigid bronchoscopies [4].

Situations where CT imaging is either unavailable or contraindicated [5].

Flexible bronchoscopy allows for direct visualization of the foreign body and guides the subsequent decision for rigid endoscopic retrieval [2,5]. In selected centers with experienced pediatric teams, flexible bronchoscopy is also increasingly utilized for therapeutic purposes [5].

SCORING SYSTEMS AND DIAGNOSTIC ALGORITHM

Clinical Scoring Systems

Several clinical scoring systems have been proposed to objectively quantify the level of clinical suspicion and guide the indications for bronchoscopy [2,3,5-8]. The scoring model developed by Fasseeh et al. (2021), validated in a cohort of 293 children, incorporates multivariate predictors including: a witnessed choking crisis, decreased breath sounds, radiographic obstructive emphysema, and unilateral wheezing [2]. The implementation of this score successfully reduced the negative bronchoscopy rate from 38% to 12% within the validation cohort [2].

A computerized predictive model utilizing six weighted variables to estimate patient-specific probabilities of foreign body aspiration based on an optimized threshold value has also demonstrated diagnostic utility [3]. These algorithmic approaches are increasingly being adopted to streamline and standardize emergency department decision-making [2,3,5].

Proposed Diagnostic Algorithm

Based on current literature and evidence-based guidelines, the following algorithm is proposed for the diagnostic management of suspected intrabronchial foreign body aspiration in pediatric patients [9]: (figure3)

DIAGNOSTIC PITFALLS AND ATYPICAL PRESENTATIONS

Several clinical scenarios can critically delay diagnosis [1,3,5]:

Unwitnessed aspiration events: Especially common in infants left unattended or under inadequate supervision [1].

Overlooked choking crises: Episodes that either pass unnoticed or are minimized/misinterpreted by parents [3].

Organic foreign bodies: Plant-based materials can undergo progressive hygroscopic swelling, causing worsening airway obstruction days or weeks after the initial aspiration event [2].

Recurrent localized pneumonia: Recurrent infections confined to the same anatomical territory that are erroneously attributed to atopy or an underlying bronchopulmonary malformation [3,5].

Unilateral wheezing misdiagnosed as asthma: Any new-onset, inaugural wheezing in a child under 3 years of age must be considered a foreign body aspiration until proven otherwise [2,5].

Bilateral or bilobar foreign bodies: Although rare (approximately 3% of cases), these can falsely reassure the clinician by preserving symmetrical findings on pulmonary auscultation [3].

Clinical Pearl: Any chronic unilateral cough, recurrent pneumonia restricted to the same anatomical segment, or unilateral wheezing in a child under 3 years of age demands that foreign body aspiration remain a primary differential diagnosis until definitively confirmed or ruled out via endoscopic evaluation [1,5].

IMPACT OF DIAGNOSTIC DELAY AND COMPLICATIONS

The time elapsed from the aspiration event to endoscopic retrieval represents the primary modifiable prognostic factor [1,3]. Current literature consistently demonstrates that a diagnostic delay exceeding 7 days is strongly correlated with a significant increase in localized complications (e.g., reactive granulation tissue, mucosal necrosis) and a heightened risk of long-term sequelae (e.g., bronchiectasis, restrictive lung disease, bronchomalacia) [1,5].

In a French longitudinal follow-up study, persistent long-term bronchial sequelae were observed in approximately 15% of children who experienced a diagnostic delay greater

than 7 days, compared to less than 2% in those who underwent early endoscopic retrieval [10].

These data fully justify a proactive diagnostic approach: when faced with even a moderate clinical suspicion, ancillary investigations (such as low-dose CT or flexible bronchoscopy) must be initiated promptly, and therapeutic rigid bronchoscopy must not be delayed out of excessive caution.

CONCLUSION

Pediatric intrabronchial foreign body aspiration requires a structured, risk-stratified approach. While plain radiography remains the first-line tool despite known limitations, low-dose chest CT, with 99% sensitivity and 98% specificity, is the modality of choice to evaluate moderate-suspicion cases and minimize negative bronchoscopies without diagnostic delay.

Rigid bronchoscopy under general anesthesia remains the diagnostic and therapeutic gold standard and must never be delayed in high-suspicion cases or respiratory distress. Integrating clinical scoring systems can standardize emergency care. Ultimately, systematically suspecting foreign body aspiration in any child with unilateral wheezing or recurrent localized pneumonia is the most effective safeguard against long-term sequelae.

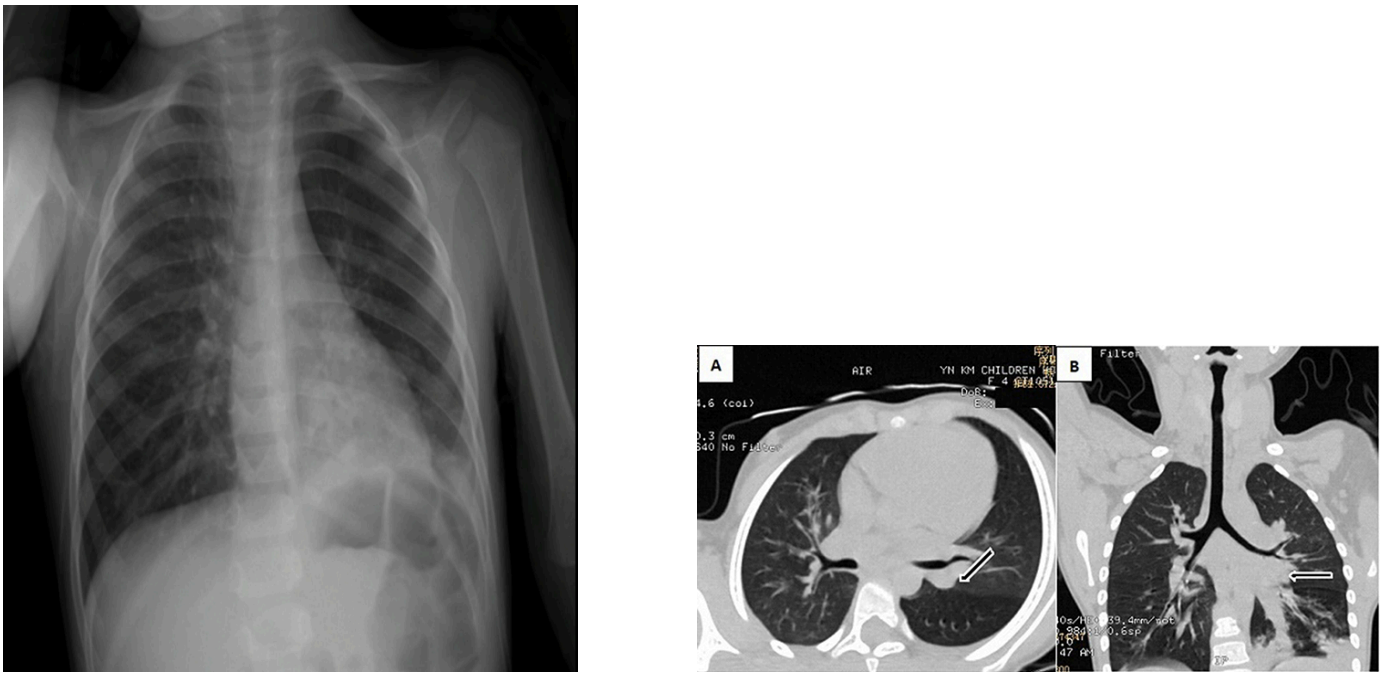


Figure 1. (a) Anteroposterior chest radiograph of a 2-year-old boy with a clinical history suggestive of foreign body aspiration. The image demonstrates a discrete asymmetry between the two lung fields along with a left retrocardiac opacity. (b) Thoracic CT scan with multiplanar reconstruction of the same boy. The image demonstrates a bronchial obstruction in the lower lobe of the left lung.

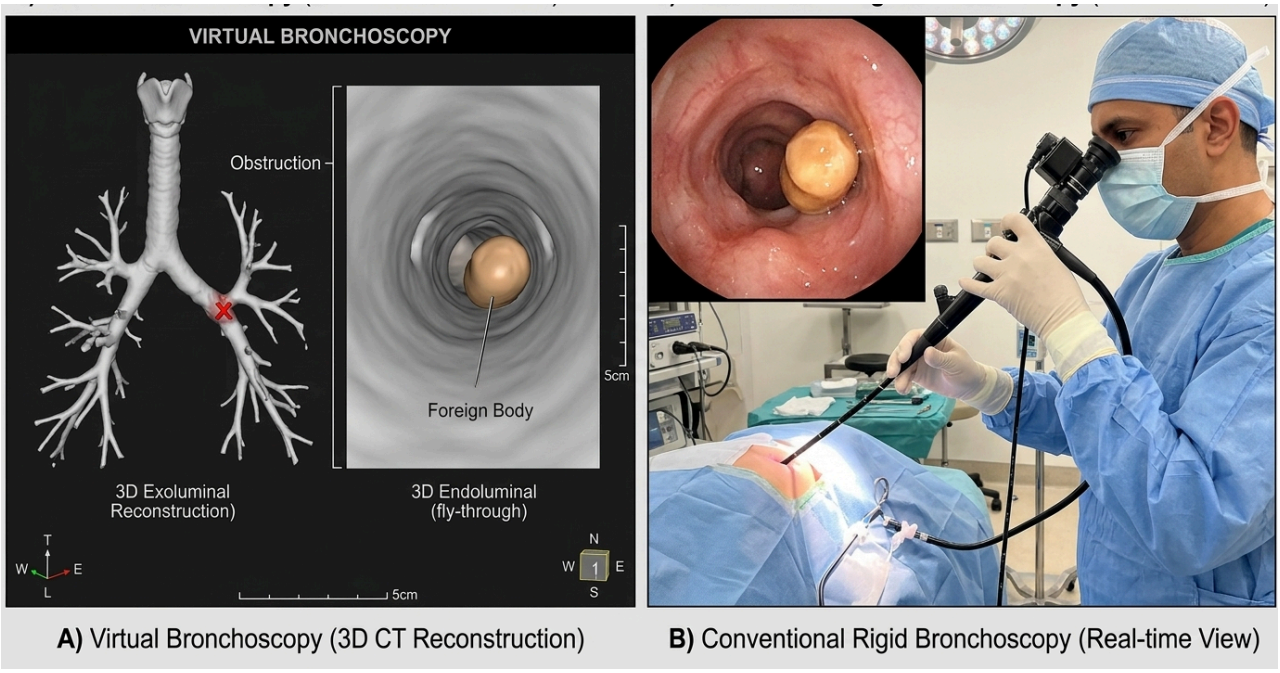


Figure 2. (A) Virtual bronchoscopy (3D CT reconstruction). (B) Conventional rigid bronchoscopy (real-time view).

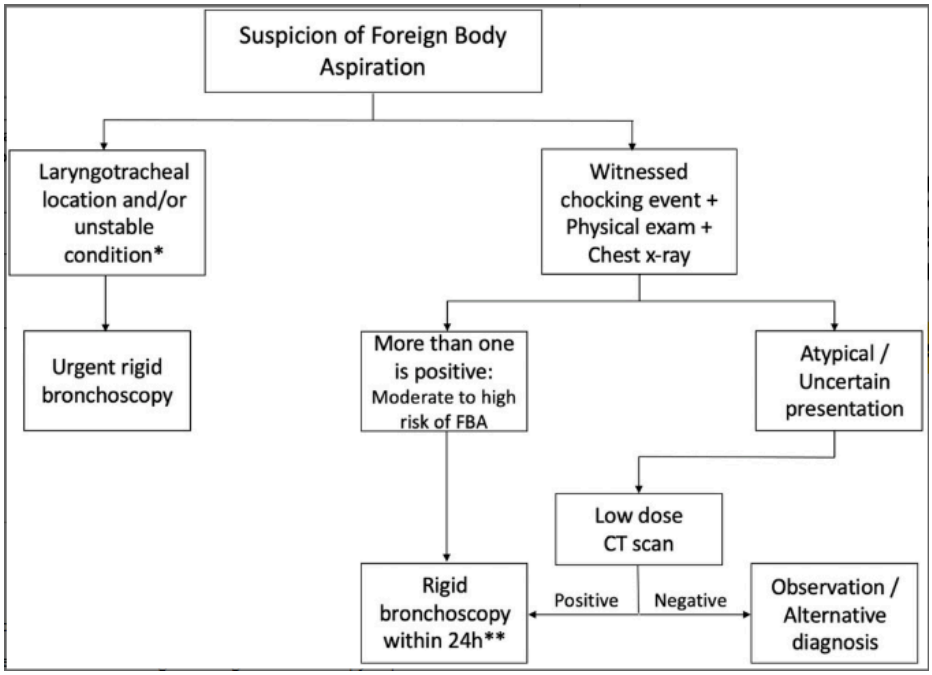


Figure 3. Diagnostic and management algorithm for suspected pediatric foreign body aspiration. *Unstable condition: severe respiratory distress, acute asphyxia, or oxygen saturation < 90% despite supplemental oxygen. **Within 24 hours or sooner if symptomatic deterioration occurs.

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