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Research paper

Endobronchial foreign body in children: can it be predictable?

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ABSTRACT

Background: Foreign body aspiration (FBA) is a critical paediatric emergency that requires prompt recognition and management to avoid severe complications. Diagnosis is challenging due to variable clinical presentations, requiring a combination of history, physical examination, and imaging. Rigid bronchoscopy remains the gold standard for diagnosis and treatment but is associated with a significant proportion of negative procedures.
Methods: We conducted a retrospective, single-centre review of paediatric bronchoscopies for suspected FBA over 30 years at CHU UCL Namur, Godinne, Belgium. Clinical, radiological, and procedural data were analysed, including symptomatology, foreign body characteristics, and follow-up outcomes.
Results: Among 99 bronchoscopies performed for suspected FBA, a foreign body was confirmed in 58 cases (59%). The highest incidence occurred in children aged 1-3 years (69%). Penetration syndrome was a strong predictor (sensitivity: 90%, Odds ratio (OR): 26.9; 95% CI:8.9-81.2, negative predictive value (NPV): 0.84). Asymmetric auscultation was the most discriminative clinical sign of FBA (specificity: 98%, OR: 42.9; 95% CI: 5.5-332.9, positive predictive value (PPV): 0.97). Unilateral hyperinflation was the most specific radiological sign (specificity: 88%, OR: 16.0; 95% CI: 5.4-47.5, PPV: 0.89). Organic foreign bodies, mainly nuts (74%), were the most common. Rigid bronchoscopy was used in 36% of cases, flexible in 37%, and both in the remaining cases. Complications occurred in 48% per-procedurally and 35% post-procedurally, but no fatalities were reported. Complete clinical recovery was achieved at 6-month follow-up.
Conclusion: Diagnosis of FBA relies on clinical examination, detailed medical history, and radiological findings, with both rigid and flexible bronchoscopy remaining essential for diagnosis and management.

1. Introduction

Foreign body aspiration (FBA) is a critical paediatric emergency, particularly affecting children aged 1 to 3 years [1,2]. This heightened risk is attributed to their natural tendency to explore their environment orally, frequent distractions during meals, lack of posterior dentition, and their underdeveloped swallowing reflex [1,3].

The classical presentation, known as penetration syndrome, typically unfolds in three distinct phases. The acute phase corresponds to a set of respiratory defence reflexes (including expulsive cough and laryngospasm) triggered by the entry of a foreign body (FB) into the airways [4]. It typically manifests as the sudden onset of a choking episode and dry, intractable coughing fit, sometimes accompanied by vomiting or cyanosis [1,4,5]. It poses an immediate risk of airway obstruction and asphyxia, which can lead to severe hypoxic brain injury or even death. This is followed by the accommodation phase, during which the FB settles in a more distal airway. Symptoms become less acute due to the accommodation of airway receptors [6]. Finally, the chronic phase develops, where complications arise from the prolonged presence of the FB in the airway lumen. These complications can manifest as bronchospasms, dyspnoea, recurrent infections, haemoptysis, and structural damage to lung tissue [1,7], underscoring the importance of early recognition and intervention to prevent long-term pulmonary sequelae.

Rigid bronchoscopy has traditionally been the gold standard for diagnosing and removing FB in suspected aspiration [8–10]. However, its extensive use has led to a significant proportion of negative bronchoscopies and carries a risk of complications. These challenges highlight the importance of careful patient selection and the complementary role of flexible bronchoscopy.

This study leverages 30 years of experience to evaluate the clinical presentation, radiological findings, and outcomes of paediatric patients undergoing bronchoscopy for suspected FBA, with the aim of improving

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diagnosis and management strategies.

2. Methods

We conducted a retrospective, single-centre review of paediatric pulmonary endoscopies performed between January 1992 and June 2022 at the CHU UCL Namur, Godinne site, within the paediatric pulmonology unit. This study focused on children aged 0 to 18 years who underwent bronchoscopy for suspected FBA. Our diagnostic and therapeutic approach was based on a management algorithm already published in 1999 by our team, which was among the first to include flexible bronchoscopy as a central tool in the evaluation of suspected FBA [11]. This algorithm served as the standard framework throughout the study period, and the methodology remained consistent over time.

Demographic data, including age and sex, were collected by reviewing the medical records of each patient, along with clinical and radiological findings. We specifically analysed the type and location of the FB and the timing of the procedure following suspicion of FBA, as well as any complications arising from the endoscopic procedures. The presenting symptoms and patient follow-up were also reviewed. A radiologist assessed radiological images, which included fluoroscopy and anterior-posterior (frontal) expiratory chest X-ray, and all bronchoscopies were performed with parental consent.

FB was classified into two groups: organic and inorganic. The duration between the aspiration event occurred, if witnessed, or when the initial respiratory symptoms occurred and the removal of the FB was grouped as less than 24 hours, less than a week, less than a month, less than a year, or more than a year. This arbitrary categorisation was intended to distinguish between different clinical scenarios: very early diagnoses (< 24 hours), typically acute and straightforward cases; short delays (< 1 week), often reflecting a more classical clinical picture as well as the time needed for cases to be referred; and longer delays (> 1 week) including long-standing occult foreign bodies (> 1 month), usually corresponding to atypical or complex cases with more insidious symptomatology.

The data was analysed with IBM SPSS Statistics (version 29.0.2.0, IBM, Armonk, NY). Normality of continuous variables was assessed using the Shapiro-Wilk test, and comparisons were made using the Mood's median test. Categorical variables were analysed with the χ^2 or Fisher's exact test, as appropriate. To account for multiple testing, we adjusted the significance level according to Bonferroni. Statistical significance was considered at p-adjusted value (p-adj) threshold of < 0.05.

The study was conducted according to the guidelines of the Declaration of Helsinki and was approved by the local Ethical Committee (CE-MG-16.2025).

3. Results

During this 30-year period, a total of 790 bronchoscopies were performed by a single experienced paediatric pulmonologist, with 114 (14%) conducted for suspected FBA. These procedures involved 99 patients aged between 8 months and 188 months, 40 of whom were referred from other centres. Detailed demographic and clinical characteristics are summarised in Table 1. A FB was identified in 58 of the 99 patients, yielding a FB-positive bronchoscopy rate of 59%. This makes FB extraction the most common interventional procedure in our centre, with an average of 1.9 extractions per year (Fig. 1).

The male-to-female ratio in confirmed FBA cases was 2.09, with the highest incidence between ages 1 and 3, accounting for 69% of cases. Over 75% of FBA cases were managed within the first week following aspiration, whereas only 3% were diagnosed more than a month after the incident. In contrast, among negative bronchoscopies, 54% were performed more than a month after the suspected aspiration. No significant difference was found between the age medians of patients with and without FB.

Penetration syndrome was present in 90% of FBA cases, but also

Table 1
Demographic of clinical features of patients with and without aspirated foreign body (AFB).

	With AFB (n=58)	Without AFB (n=41)	p-adj*
Sex Ratio (M/F)	2.05 (39/19)	2.15 (28/13)	NS
Median age in months (range)	26 (9-188)	28 (8-126)	NS
• Aged 12 – 36 months, n (%)	40 (69)	22 (54)	
Time to treatment, n (%)			
< 1 day	21 (36)	7 (17)	NS
1 day – 1 week	23 (40)	6 (15)	NS
1 week– 1 month	12 (21)	6 (15)	NS
1 month – 1 year	1 (2)	13 (32)	0.002
> 1 year	1 (2)	9 (22)	0.034
Symptoms, n (%)			
Penetration syndrome	52 (90)	10 (24)	0.002
Cough	40 (69)	31 (76)	NS
Wheezing	27 (47)	23 (56)	NS
Stridor	3 (5)	1 (2)	NS
Fever	7 (12)	3 (7)	NS
Physical examination, n (%)			
Normal	8 (14)	15 (37)	NS
Unilateral or localised wheezing	7 (12)	2 (5)	NS
Bilateral wheezing	13 (22)	23 (56)	0.014
Asymmetric auscultation	30 (52)	1 (2)	0.002
$TcSO_2$ < 95%	15 (26)	3 (7)	NS
Radiological findings, n (%)			
Normal X-ray	9 (16)	14 (34)	NS
Infiltration	5 (9)	6 (15)	NS
Unilateral or localised hyperinflation	40 (69)	5 (12)	0.002
Bilateral hyperinflation	1 (2)	9 (22)	0.034
Atelectasis	0 (0)	7 (17)	0.036
Radiopaque object	4 (7)	0 (0)	NS
Fluoroscopy	21(55)	2 (13)	NS
Not performed	*20 (34)*	*25 (61)*	

* p-value (χ^2 or Fisher's exact test, as appropriate) were adjusted for multiple testing using the Bonferroni correction.
$TcSO_2$: transcutaneous oxygen saturation; NS: Non-significant (p-adj >0.05); M: male; F: female.

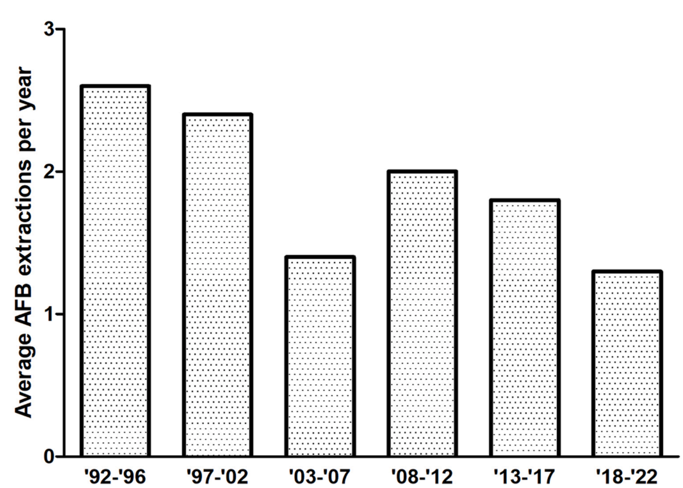

Fig. 1. Evolution of the average annual rate of aspirated foreign body (AFB) extractions per 5-year period between 1992 and 2022 in our centre.

occurred in 24% of non-FBA cases. This makes it a statistically significant sign of FBA (p-adj: 0.002) with a sensitivity of 90%, a negative predictive value (NPV) of 0.84, and an odds ratio (OR) of 26.9 (95% confidence interval (CI): 8.9-81.2) (Table 2). Other major symptoms

Table 2
Diagnostic performance of clinical and radiological features.

	Sensitivity %	Specificity %	PPV	NPV	OR [95% CI]
Symptoms					
Penetration syndrome	90	76	0.84	0.84	26.9 [8.9, 81.2]
Cough	69	24	0.56	0.36	0.7 [0.3, 1.8]
Wheezing	47	44	0.54	0.37	0.7 [0.3, 1.5]
Stridor	5	98	0.75	0.42	2.2 [0.2, 21.8]
Fever	12	93	0.70	0.43	1.7 [0.4, 7.2]
Physical examination					
Normal	14	63	0.35	0.34	0.3 [0.1, 0.7]
Unilateral or localized wheezing	12	95	0.78	0.43	2.7 [0.5, 13.6]
Bilateral wheezing	22	44	0.36	0.29	0.2 [0.1, 0.5]
Asymmetric auscultation	52	98	0.97	0.59	42.9 [5.5, 332.9]
$TcSO_2 < 95\%$	26	93	0.83	0.47	4.4 [1.2, 16.4]
Radiological findings					
Normal X-ray	16	66	0.39	0.36	0.4 [0.1, 0.9]
Infiltration	9	85	0.45	0.40	0.6 [0.2, 1.9]
Unilateral or localized hyperinflation	69	88	0.89	0.67	16.0 [5.4, 47.5]
Bilateral hyperinflation	2	78	0.10	0.36	0.1 [0.0, 0.5]
Atelectasis	0	83	0.00	0.37	-
Radiopaque object	7	100	1.00	0.43	-

PPV: positive predictive value; NPV: negative predictive value; OR: odds ratio; CI: confidence interval; $TcSO_2$: transcutaneous oxygen saturation.

Table 3
Clinical outcomes, foreign body property and follow-up of foreign body aspiration (FBA) cases.

Foreign body characteristics and procedural outcomes	
Foreign body location, n (%)	
Right bronchial tree	31 (53)
Left bronchial tree	24 (41)
Both bronchial tree	3 (5)
Foreign body type, n (%)	
Organic	48 (83)
• Peanut	35 (60)
• Walnut	3 (5)
• Hazelnut	2 (3)
• Meat	2 (3)
• Cashew nut	2 (3)
• Pistachio	1 (2)
• Bread with nuts	1 (2)
• Corn kernel	1 (2)
• Wheat seed	1 (2)
Non-organic	10 (17)
• Pushpin	2 (3)
• Tracheostomy cannula	1 (2)
• Full pearl	1 (2)
• Ring	1 (2)
• Pen cap	1 (2)
• Cushion foam	1 (2)
• Confetti	1 (2)
• Disinfectant tablet	1 (2)
• Suspender clip	1 (2)
Bronchoscopy type, n	
Rigid	36
Flexible	37
Flexible converted in rigid	11
Rigid then flexible	9
Rigid then flexible converted in rigid	6
Median hospitalisation duration, days (range)	2 (1-9)
Procedure-related complications, n (%)	
Mortality	0 (0)
Multiple procedures	15 (26)
Per-procedure	28 (48)
• Bleeding of the airway mucosa	8 (14)
• Transient hypoxia	11 (19)
• Laryngobronchospasm	9 (16)
Post-procedure	20 (35)
• Fever	9 (16)
• Laryngobronchospasm	1 (2)
• Abnormal chest X-ray	10 (17)
Complete clinical recovery at 6 months, n (%)	58 (100)

included cough (69%), wheezing (47%), stridor (5%), and fever (12%). However, these did not show statistical significance.

On physical examination, findings were strictly normal in 14% of FBA cases. Unilateral wheezing was observed in 12% of FBA cases, and bilateral wheezing in 22%, a significantly lower proportion compared to children without FBA (56%, p-adj: 0.014). Asymmetric auscultation was the most discriminative sign of FBA, observed in 52% of affected children compared to 2% in those without aspiration (p-adj: 0.002, OR: 42.9 (95% CI: 5.5-332.9), positive predictive value (PPV): 0.97).

Radiologically, 16% of FBA cases had normal findings, while others showed multiple abnormalities. Unilateral hyperinflation was the most specific radiological criterion, with a specificity of 88% and an OR of 16.0 (95% CI: 5.4-47.5). It was the only statistically significant radiological finding favouring FBA (p-adj: 0.002, PPV: 0.89).

Most FB were organic, particularly nuts (74%), with peanuts accounting for 60%, and a smaller proportion were inorganic (17%). Only 7% of FB were radiopaque. FB were slightly more frequently located in the right bronchial tree (53%), compared to the left side (41%) or bilaterally (5%). Detailed FB properties and clinical outcomes are summarised in Table 3. In cases where no FB was found, most patients were diagnosed with either virus-induced asthma or bronchitis (n=36). Additionally, one patient had viral laryngotracheobronchitis, two were diagnosed with bacterial tracheitis requiring admission to the paediatric intensive care unit, and two others had protracted bacterial tracheobronchitis, with preprocedural cultures positive for *Haemophilus influenzae*.

Rigid bronchoscopy was used in 36% of interventions, flexible bronchoscopy in 37%, and both flexible and rigid bronchoscopy were used in the remaining cases, requiring conversions between the two when appropriate. Following the procedure, patients were hospitalised for monitoring, with a median duration of 2 days (range 1 to 9 days). Patients with straightforward extractions were generally discharged the next day. However, hospital stays were prolonged in cases requiring multiple interventions and additional treatments. For patients with granulomas, intravenous corticosteroids were given for 3 days, followed by oral corticosteroids to complete a total of 7 days. In suppurative cases, intravenous antibiotics were administered for 24 hours, followed by oral antibiotics for a total of 7 days. Some complications were observed during (48%) and/or after (35%) the procedure, but no fatalities were recorded. These complications sometimes necessitated administration of supplemental oxygen, inhaled bronchodilators, inhaled corticosteroids, or antipyretics as needed.

In 15 children, a second procedure using flexible bronchoscopy was required. Among these, 10 cases were due to persistent abnormal chest X-rays, while 5 were related to complicated initial procedures or significant surrounding granulation tissue. Of these 15 cases, 6 ultimately required a conversion to a rigid bronchoscopy.

In all cases, clinical recovery *ad integrum* was achieved at the 6-

month follow-up, which included a normal V/Q scintigraphy at 3 or 6 months in cases requiring multiple interventions. This imaging modality was chosen to assess pulmonary integrity non-invasively, minimizing radiation exposure compared to CT scans, particularly in children and during earlier decades (1990–2010). This choice was supported by a study highlighting its sensitivity for detecting sequelae or residual FB, particularly at the 6-month follow-up, where it proved more informative than standard chest X-rays [12].

4. Discussion

In this study, we retrospectively evaluated the association between clinical presentation, radiological findings, and patient history with the presence of a FB confirmed by bronchoscopy. Our results highlight the importance of systematically combining these three dimensions during the diagnostic process. Furthermore, we emphasize the need for expertise in both flexible and rigid bronchoscopy to ensure accurate diagnosis and effective management.

Since the 1960s, the incidence of FBA has shown a significant decline, largely attributed to the implementation of effective public health policies [13,14]. However, recent data indicate a stabilization or even an increase in cases over the past decade [15,16]. In 2019, the global incidence of FBA among children under five years old was 1.1 per 1000, with rates exceeding 3.5 per 1000 in some European countries and nearly 2.5 per 1000 in Belgium [16]. More recently, in 2023, 51 cases of FB extraction were reported in the paediatric population under 18 in Belgium [17]. In our cohort, we also observed a decline in the annual number of FBA extractions over the years, followed by a relative stabilisation (Fig. 1).

FBA continues to be a critical health concern, as it remains the leading cause of accidental deaths in infants and the fourth most common cause of death in preschool children [1]. The economic burden is also considerable, with annual direct costs estimated at $50 million in Europe in 2003 [18] and increasing, as illustrated in the United States where healthcare costs associated with FBA in children rose from $93 million in 2000 to $486 million in 2009 [19], although one other study suggest more conservative annual estimates of about $41 million [20].

Despite advances in diagnostic techniques, identifying FBA remains challenging, as illustrated by the 41% rate of negative bronchoscopy in our study. A key difference between negative and positive cases lies in the delay between the suspected event and the bronchoscopy. This reveals two distinct clinical patterns: cases with acute and typical presentations, supported by a clear clinical history and consistent clinical and/or radiological findings, are generally managed promptly and more likely to yield positive bronchoscopy results. Conversely, cases with insidious or atypical symptoms tend to be investigated later. The longer the delay between aspiration and bronchoscopy, the less reliable the parental history becomes and the more atypical the clinical and radiological signs tend to be, increasing the risk of either missing relevant investigations or performing a bronchoscopy that finds no aspirated FB. However, long-standing FB, often called occult foreign bodies, carry a higher risk of pulmonary damage and are more difficult to remove, frequently requiring multiple or even surgical interventions [2,21–24]. Animal studies suggest lung injury can begin as early as five days after aspiration [25]. In our cohort, about 25% of cases (n=14) were managed more than a week after the event, but only two involved aspirations that occurred over a month prior.

In terms of FB localization, a slight predominance in the right bronchial tree was observed, consistent with many other studies [1,7,21,22,26,27]. This is due to the wider, more vertical right bronchus, which favours FB lodgement. However, this anatomical predisposition is less pronounced in children [28,29].

Consistent with other studies [1,2,5,7,22,29,30], organic FBs were the most common in our study. The nature of the FB in pulmonary injury remains debated: while some studies report no significant difference between organic and inorganic materials to induce pulmonary damage [25], others highlight that the oil-rich materials appear to be associated with a prolonged pulmonary recovery even after retrieval of the FB, suggesting a role in the severity of inflammation and pulmonary injury [29,31,32].

FBA presentations are highly variable, influenced by the type, size, and location of the aspirated FB, as well as the duration between aspiration and clinical evaluation. Cough is the most common symptom, reported in over 80% of cases, followed by dyspnoea, but both lack specificity [7,22,27,30].

Lowe *et al.* reviewed over ten studies and concluded that bronchoscopy is not warranted based solely on history if clinical and paraclinical findings are normal [33]. In contrast, Sahin *et al.* advocate for tracheobronchial endoscopy based on the sole presence of a suspected penetration syndrome [27]. Indeed, the literature is divided: some studies show that witnessed aspiration has low sensitivity and specificity [33–35], while others identify it as the strongest predictor of FBA [4,23,26,27,36,37]. In our study, penetration syndrome showed high sensitivity and a strong association with FBA. Notably, several patients with normal clinical and radiological examinations and minimal symptoms were ultimately diagnosed with an aspirated FB solely based on a highly suggestive history, even when the delay between the suspected event and the bronchoscopy was longer than 1 week. This adds to the findings of the meta-analysis by Cohen *et al.*, the importance of a thorough clinical history [30]. When history is strongly suggestive, further evaluation should be pursued, even in the presence of minimal [or no] symptoms. Some children likely expelled the FB spontaneously through coughing, explaining negative bronchoscopy findings despite penetration syndrome.

This variability of choking presentation underscores the need for thorough clinical assessment. Our study, in line with existing literature, confirms that unilaterally decreased breath sounds are the more specific sign for FBA [27,30,36–40]. However, it's worth mentioning that normal clinical findings do not exclude the diagnosis [30,31,40]. Imaging also plays a crucial role in FBA diagnosis, though the optimal modality remains debated. Chest X-ray is the first-line investigation, with inspiratory and expiratory antero-posterior (frontal) views preferred in cooperative children. However, X-rays frequently fail to detect non-radiopaque FB, with radiopacity observed in less than 20% of cases [1,4,5,26,38–41]. In our study, localised hyperinflation was the most common finding across all age groups, consistent with previous reports [5,30,33,35–37,40]. Moreover, up to 50% of cases may show no abnormalities on chest X-ray, potentially warranting the use of additional imaging modalities such as fluoroscopy, ultrasound, or low-dose CT-Scan in select cases to avoid unnecessary bronchoscopy [1,4,34,36], although these modalities, including chest CT, may still fail to identify an inhaled FB, particularly when it is radiolucent and composed of small organic material [42,43].

Rigid bronchoscopy remains the gold standard for FB removal, as supported by American and European task forces [8–10], providing secured airway control, superior visualization, and effective extraction, especially in paediatric cases where smaller airways increase obstruction risks [44]. However, it requires general anaesthesia and carries risks of airway trauma, bleeding, and oedema, with complication rates reaching up to 47% but usually around 10% (though our data show slightly higher rates) and a 0 to 1.1% mortality rate in Europe [37,40,44,45].

Flexible bronchoscopy offers a less invasive option with fewer complications but can impair ventilation, reduce visibility due to secretions, and increase FB displacement risk [8]. Its utility lies in superior visualization of distal airways and as a diagnostic tool when FB aspiration is uncertain, though its use in children is debated due to higher hypoxemia risk and limited paediatric tools [26,44].

Given these considerations, both techniques are complementary, with each offering distinct advantages and limitations. An integrated approach with flexible bronchoscopy as a diagnostic step and rigid bronchoscopy as a therapeutic backup optimizes safety and outcomes, particularly in complex cases. Training programs should emphasize proficiency in both methods and smooth conversion between them. Achieving this expertise is not straightforward, generally requiring over five years of experience and a substantial procedural volume [46]. Secondary local centres may offer the advantage of immediate access, potentially shortening the delay to intervention and reducing morbidity. However, this depends on the availability of appropriate equipment, technical expertise, and a multidisciplinary team, including an experienced paediatric anaesthetist [8–10,36]. Complication rates and incomplete extractions are significantly lower in high-volume centres or when procedures are performed by well-trained personnel with extensive experience [46]. Therefore, the decision to perform bronchoscopy locally or to transfer to a specialised centre should be guided by patient stability, foreign body characteristics, and institutional capabilities, carefully balancing the advantage of rapid intervention against the need for expertise.

A sustained and ongoing commitment to prevention is essential to mitigate the risks and mortality associated with FBA. Public health education targeting parents and caregivers must emphasize age-appropriate safe feeding practices, vigilant supervision during meals and playtime, avoidance of high-risk foods, and the creation of safe environments for young children [3]. Special attention is needed for children with developmental or neurological delays, and older siblings should be educated about the dangers of sharing small toys or foods. Paediatricians, nurses at maternal and child health centres, general practitioners, midwives, and healthcare organizations play a crucial role in delivering this education.

Equally vital is the broad implementation of first aid, cardiopulmonary resuscitation, and choking rescue training, currently hindered by its voluntary nature and adult-centred focus. Initiatives like the European Kids Save Life program demonstrate the value of teaching these lifesaving skills to younger audiences [47]. Expanding and integrating FBA prevention into such programs can significantly enhance their impact.

Finally, preventive efforts must also be supported by strict regulations on packaging and toy safety [2], reinforced through public awareness media campaigns and backed by regularly updated safety guidelines in nursery and schools to maintain an effective framework.

5. Conclusion

Diagnosis of FBA in children relies on a thorough and detailed clinical history, along with clinical signs and imaging. Penetration syndrome, asymmetric breath sounds, and unilateral hyperinflation on X-rays are strong indicators. However, symptoms can be variable, and normal findings may complicate diagnosis. Both rigid and flexible bronchoscopy are essential for effective management, and timely intervention ensures excellent long-term outcomes.

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Declaration of competing interest

The authors declare that they have no potential conflict of interest regarding this submitted manuscript.

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