



Evaluation of Foreign body aspiration score (FOBAS) in children- A retrospective cohort study

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Abstract

Foreign Body Aspiration (FBA) is a common medical emergency among young children, but the evaluation and management of a suspected FBA case can vary across physicians and centers. We aimed to identify which clinical, laboratory, and radiological findings can predict FBA in children and to evaluate a clinical score to improve FBA prediction. This is a retrospective cohort study of patients aged 0–18 years admitted to Soroka University Medical Center between 2010 and 2020 with suspected FBA. All patients underwent flexible bronchoscopy and were divided into positive and negative FBA groups. A newly developed foreign body aspiration score (FOBAS), based on medical history, physical examination, and chest X-ray findings, was evaluated for its predictability. The study included 412 children (median age 21 months, 56.8% females), of whom 154 (37.4%) had FBA and 258 (62.6%) did not. Multivariate regression analysis showed exposure to nuts/seeds, unilateral wheezing or decreased breath sounds, stridor, and suggestive findings on chest X-ray were significant risk factors for FBA (OR [95%CI] -1.994[1.290–3.082], 1.487[1.206–1.832], 1.883 [1.011–3.509] and 2.386[1.917–2.970], respectively). However, a choking episode, acute cough, and absence of fever and rhinorrhea did not predict FBA. FOBAS showed an increased risk of FBA for each additional point of the score, with an odds ratio of 1.572 (95% CI—1.389–1.799).

Conclusion: FOBAS is a good predictor for the presence of FBA in children. Once prospectively validated, FOBAS could aid in decision-making at the emergency department, enabling more standardized care, reducing unnecessary procedures, and leading to better clinical outcomes.

What is Known:

- The evaluation and management of a child with suspected foreign body aspiration (FBA) vary across physicians and centers, without a consensus regarding the indications and criteria for performing bronchoscopy.
- Flexible bronchoscopy is the standard procedure for the diagnosis and sometimes treatment of FBA in children, but it may hold potential complications.

What is New:

- We propose a newly developed foreign body aspiration score (FOBAS), based on medical history, physical examination, and chest X-ray findings, for the prediction of FBA in children at the emergency department.
- The FOBAS is a good predictor of FBA in children. The score enables more standardized care and may reduce unnecessary procedures.

Keywords Foreign Body Aspiration · Score · Algorithm · Emergency department · Bronchoscopy · Children

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Introduction

Foreign Body Aspiration (FBA) is a common medical emergency in young children that can lead to life-threatening respiratory events, suffocation, and even death [1]. In 2020, the National Safety Council classified it as the fourth leading cause of preventable death in children aged 1–4 years in the United States [2]. While organic food parts such as nuts, seeds, and fruit slices are the most common foreign bodies (FB), they can also be inorganic, such as plastic or metal. The clinical presentation varies, ranging from asymptomatic to complete airway obstruction [3, 4]. Unrecognized or delayed diagnosis of FB can lead to complications such as pneumonia, atelectasis, failure to thrive, bronchiectasis, and even lobectomy in severe cases [3–8]. Bronchoscopy is the standard procedure for the diagnosis and treatment of FBA. As it is an invasive procedure, it is usually performed under general anesthesia in the operating room. Although it is generally considered a safe procedure, there are potential complications such as airway injuries, bronchospasm, desaturation, local edema, and bleeding [6–11]. Flexible bronchoscopy is commonly used for diagnosis, while rigid bronchoscopy is used for FB extraction in most institutions [6, 7, 12].

Currently, there is no consensus regarding the indications and criteria for performing bronchoscopy, and each center typically has its own protocols based on medical history, physical examination, radiological findings, and decisions of the treating physician [6, 12–14]. While several different scores and algorithms have been suggested to predict the presence of an FBA, none have proven to be sufficiently specific or sensitive enough to confirm the diagnosis [5, 13–16]. Although some studies have proposed algorithms for predicting FBA based on history, physical findings, and radiological evaluation [17], most of them have not been validated by a prospective study [13–16, 18–20].

This study aimed to identify clinical parameters with predictive value for FBA in children and to evaluate the effectiveness and sensitivity of a newly developed foreign body aspiration score (FOBAS) in predicting FBA.

Methods

Study population

This is a retrospective study conducted at the Soroka University Medical Center (SUMC), a tertiary hospital in the south of Israel. It included patients aged 0–18 years that were admitted to the emergency department (ED) between January 2010 and June 2020, for a suspected FBA, and who underwent flexible bronchoscopy. Demographics, clinical history, vital signs, physical examination, complete blood

count, C-reactive protein, and radiological findings (Posterior-anterior (PA) and lateral chest X-ray) were collected from medical records. The study was approved by the local Ethics Committee of SUMC (No. 0290–19–SOR).

Statistical analysis

Demographic and clinical parameters such as – a choking episode, sudden cough, exposure to nuts, rhinitis, stridor, dyspnea, fever, respiratory rate, room air saturation, complete blood count, C-reactive protein, auscultation findings, and radiological findings were statistically analyzed, and compared between those who had a FB upon bronchoscopy (positive FBA group) and those who did not have (negative FBA group), using the appropriate univariate analyses. Specifically, nominal variables were compared using Pearson's χ^2 test, and continuous variables that matched parametric criteria were compared by using Student's t-test. Ordinal variables and continuous variables that did not match parametric criteria were compared by using Mann–Whitney U tests. Statistical significance was set at a p-value of 0.05. Multivariate logistic regression analysis was used to assess the odds ratio (OR) and significance for FBA associated with the component of the proposed score adjusted to demographic features. Finally, ROC analysis was performed on FOBAS > 4 and FOBAS > 7 to assess the sensitivity and specificity of the score and its ability to predict FBA.

Results

This study involved 502 patients who underwent flexible bronchoscopy for suspected FBA. Forty-eight children were excluded as they were referred directly to the pulmonary clinic and did not receive an ED assessment. An additional 42 children were excluded as they did not have a chest x-ray in the database. The final analysis included 412 children, with 154 (37.4%) patients in the positive FBA group (a FB was observed during flexible bronchoscopy) and 258 (62.6%) in the negative FBA group (no FB was observed during flexible bronchoscopy). Demographics revealed that the median age was 1.9 years (IQR 1.0–5.8), 56.8% were females, and 64.6% were of Bedouin Arab descent. Most of the children (92.7%) were previously healthy while a small percentage had a history of asthma or wheezing (3.2%), neurodevelopmental disorder (2.5%), or failure to thrive (1.5%). Other types of medical histories such as cardiac, gastroenterological, nephrological, or genetic conditions were not statistically significant and were not included in the study. Table 1 presents the demographic and clinical data.

In this study, the positive FBA group (n = 154) and the negative FBA group (n = 258) were compared based on clinical, physical, laboratory, and radiological parameters.

Table 1 – Comparison of demographic and clinical characteristics between patients with Foreign Body Aspiration (positive FBA) and without FBA (negative FBA)

	Positive FBA 154 (37.4%)	Negative FBA 258 (62.6%)	p-value	Total 412 (100%)
Sex (female) ^a	85 (55.2%)	149 (57.8%)	0.612	234 (56.8%)
Origin (Bedouin) ^a	118 (76.6%)	148 (57.4%)	<0.001	266 (64.6%)
Age (years and months) ₆ ;	2.0 [1.2–7.6]	1.9 [1.0–5.1]	0.078	1.9 [1.0–5.8]
Comorbidity ^a	7 (4.5%)	23 (9.0%)	0.093	30 (7.3%)
Choking episode ^a	91 (59.1%)	149 (57.8%)	0.954	240 (58.3%)
- none	63(40.9%)	109(42.2%)		172 (41.7%)
- suspected/observed				
Exposure to nuts/seeds ^a	58 (37.7%)	60 (23.3%)	0.002	118 (28.6%)
Acute persistent cough ^a	112 (72.7%)	176 (68.2%)	0.334	288 (69.9%)
Fever (≥ 37.5) ^a	34 (22.1%)	61 (23.6%)	0.715	95 (23.1%)
Respiratory rate ^b	32 [26–40]	30 [24–36]	0.046	32 [26–40]
O ₂ blood saturation ^b	98 [96–100]	98 [97–100]	0.012	98 [96–100]
Rhinorrhea ^a	11 (7.1%)	41 (15.9%)	0.010	52 (12.6%)
Without fever or rhinorrhea ^a	112 (72.7%)	171 (66.3%)	0.172	283 (68.7%)
Stridor ^a	23 (14.9%)	22 (8.5%)	0.044	45 (10.9%)
Unilateral breath findings (wheezing/ reduced air entry) ^a	74 (48.1%)	72 (27.9%)	<0.001	146 (35.4%)
CXR suggestive of foreign body ^a	109 (70.8%)	77 (29.8%)	<0.001	186 (45.1%)
CXR findings	45 (29.2%)	40 (15.5%)	<0.001	85 (20.6%)
Unilateral hyperinflation	6 (3.9%)	7 (2.7%)		13 (3.2%)
Atelectasis	8 (5.2%)	25 (9.7%)		33 (8.0%)
Unilateral hyperinflation & atelectasis on one-side	2 (1.3%)	5 (1.9%)		7 (1.7%)
consolidation	46 (29.9%)	0		46 (11.2%)
Radiopaque foreign body				
FOBAS	5 [4–6]	3 [2–4]	<0.001	4 [3–5]
FOBAS groups; _a	36 (23.4%)	143 (55.4%)	<0.001	179 (43.4%)
Score 1–3	83 (53.9%)	99 (38.4%)		182 (44.2%)
Score 4–6	35 (22.7%)	16 (6.2%)		51 (12.4%)
Score 7–10				

^aNominal characteristics are represented as sum (n, %) and compared via Pearson's χ^2 test

^bOrdinal and continuous variables that do not match parametric criteria are described as median and interquartile range [IQR] and compared via Man Whitney U tests

The results showed that a history of a choking episode and acute persistent cough did not significantly differ between the groups (40.9% vs 42.2%, $p=0.954$ and 72.7% vs 68.2%, $p=0.334$, respectively). However, exposure to nuts or seeds was significantly higher in the positive FBA group (37.7% vs 23.3%, $p=0.002$). Clinical features of physical examination differed between groups. Rhinorrhea was two times higher in the negative FBA group (15.9% vs 7.1% vs, $p=0.010$), while stridor was almost two times higher in the positive FBA group (14.9% vs 8.5, $p=0.044$). Unilateral wheezing and decreased air intake were significantly higher in the positive FBA group (26.0% vs 13.2%, $p<0.001$ and 31.8% vs 19.8%, $p=0.006$, respectively). The absence of fever and rhinorrhea were not significantly different between the groups, and neither were oxygen saturation and respiratory rate.

Chest x-rays were interpreted by a radiologist as suggestive of FBA or not, according to the following find-

ings: unilateral hyperinflation, lobar atelectasis/ infiltrate, hyperinflation in combination with atelectasis in the same hemithorax, and radio-opaque foreign body. Overall, findings on chest X-rays suggestive of FBA were significantly higher in the positive FBA group compared with the negative FBA (70.8% vs 29.8%, $p<0.001$). However, laboratory test results including complete blood count and C- Reactive Protein (CRP), were not statistically different between the groups.

The FOBAS score

The FOBAS (Fig. 1) is a clinical score that was developed at our center to help predict FBA in the ED. It comprises medical history, physical examination, and radiological findings, and is scored as follows: a choking episode (0-no, 2-suspected or observed), exposure to nuts (0-no, 1-yes), a sudden

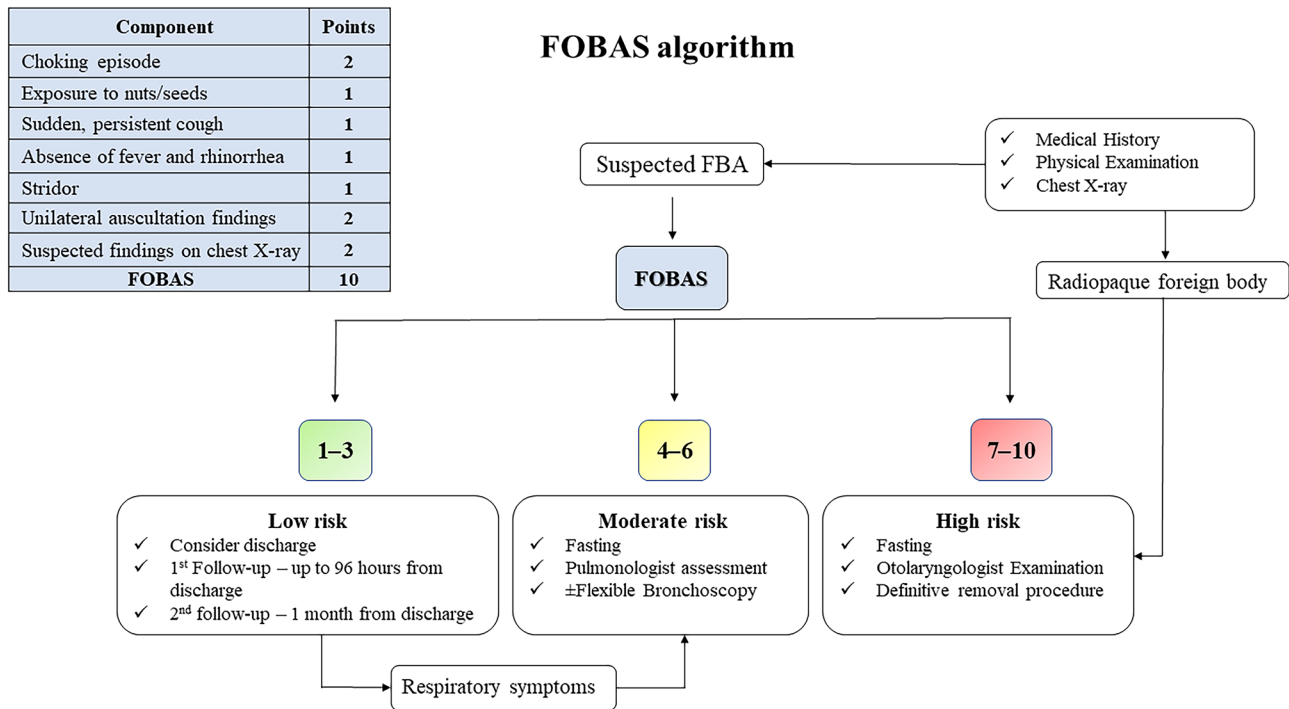


Fig. 1 FOBAS scoring system

cough during or after the event (0-no, 1-yes), absence of fever (≥ 37.5 °C) combined with an absence of rhinorrhea (0-no, 1-yes), unilateral wheezing or decreased air entry on auscultation (0-no, 2-yes), the presence of stridor (0-no, 1-yes), and imaging findings suggestive of FBA on chest x-ray such as unilateral hyperinflation/atelectasis/infiltrate

(0-no, 2-yes). A radiopaque foreign body is assigned a full 10 points, regardless of other components of the score. The total score ranges from 0 to 10 (lowest to highest risk). Based on the total score, each child was classified into one of three risk groups: low (1–3 points), moderate (4–6 points), or high (7–10 points).

Fig. 2 Forest plot presenting the odds ratios (OR) of the individual components of FOBAS

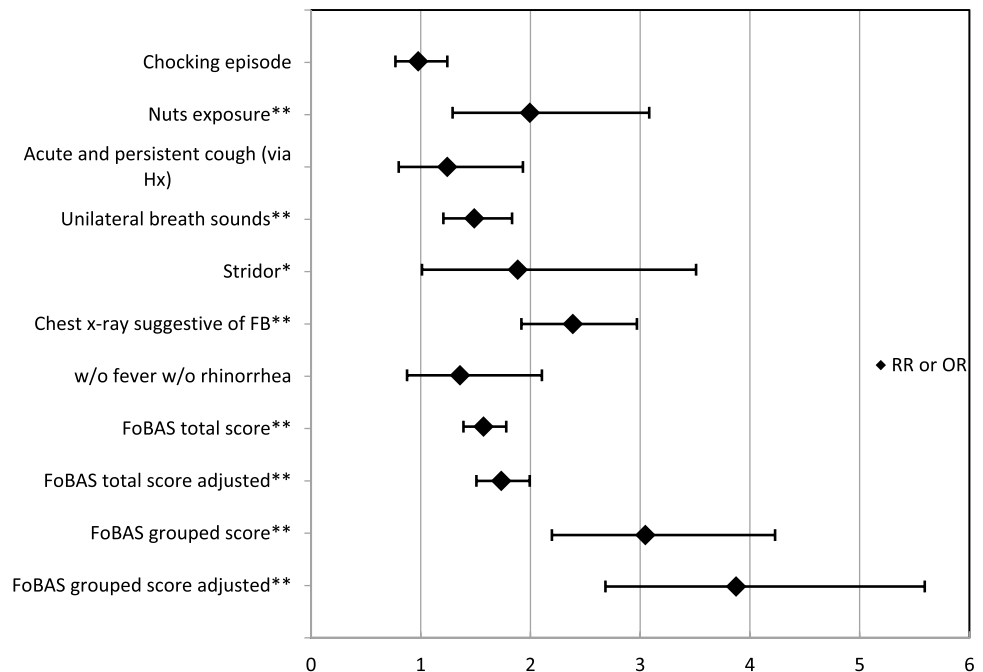


Table 2 – Association of score components with foreign body aspiration: univariate and multivariate logistic regression analysis with Odds Ratio (OR) and 95% confidence interval (CI)

Variables in the model	OR	p-value	95% CI
Chocking episode	0.977	0.850	0.769–1.242
Nuts/seeds exposure**	1.994	0.002	1.290–3.082
Acute and persistent cough	1.242	0.335	0.799–1.931
Unilateral breath sounds **	1.487	<0.001	1.206–1.832
Stridor*	1.883	0.046	1.011–3.509
Chest x-ray suggestive of FB**	2.386	<0.001	1.917–2.970
w/o fever & w/o rhinorrhea	1.357	0.173	0.875–2.104
FOBAS total score (OR per each additional point of score)**	1.572	<0.001	1.389–1.779
FOBAS adjusted for sex, age, and ethnicity**	1.733	<0.001	1.507–1.993
FOBAS grouped score (OR per grouped risk – low/moderate/high)**	3.047	<0.001	2.195–4.229
FOBAS grouped score adjusted for sex, age, and ethnicity**	3.873	<0.001	2.683–5.593

*p ≤ 0.05; **p ≤ 0.001

Table 2 displays the results of the multi and univariate logistic regression analysis of the FOBAS score components and their association with the presence of a FB on bronchoscopy. The analysis found that exposure to nuts or seeds,

unilateral breath sounds (decreased or wheezing), stridor, and suggestive findings on chest x-ray were all statistically significant risk factors for FBA (OR 1.994, p = 0.002; OR 1.487, p < 0.001; OR 1.883, p = 0.046; OR 2.386, p < 0.001,

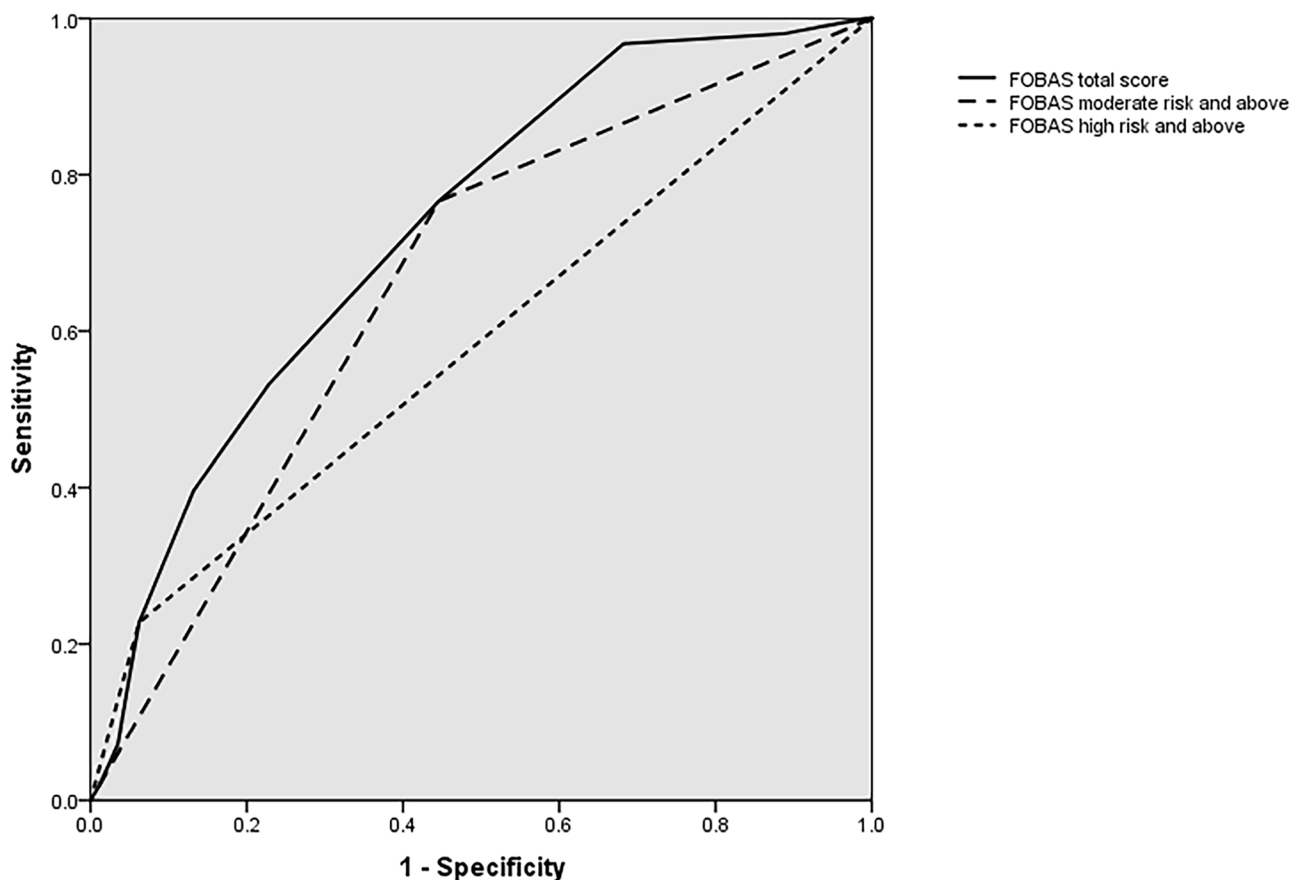


Fig. 3 The area under the ROC curve for FOBAS total score, FOBAS moderate-risk and above, and FOBAS high-risk

Table 3 – Sensitivity, Specificity, and Predictive Ability of FOBAS

	Sensitivity	Specificity	PPV	NPV	AUC [95% CI]
FOBAS (All score components)	-	-	-	-	0.729** [0.681–0.778]
FOBAS Moderate- risk and above (> 4)	76.6%	55.4%	50.6%	79.9%	0.660** [0.607–0.714]
FOBAS high risk (> 7)	22.7%	93.8%	68.6%	67.0%	0.583** [0.524–0.641]

PPV positive predictive value, NPV Negative predictive value, AUC area under the curve

respectively). Conversely, the absence of fever and rhinorrhea, choking episodes, and sudden cough were not significant risk factors for FBA. A graphical representation of the OR values of the different FOBAS components is presented in Fig. 2. The total FOBAS was also found to be a significant risk factor for FBA (OR 1.572, $P < 0.001$) even after adjusting for sex, age, and ethnicity (OR 1.733, $P < 0.001$), with an increased chance of 1.73 for each additional point of the score. When stratified by risk groups the chances of FBA were even higher with OR values of OR 3.047 and 3.876 ($p < 0.001$), before and after adjusting for sex, age, and ethnicity, respectively.

Finally, the ability of the FOBAS to predict FBA was evaluated using Receiver Operating Characteristics (ROC) analysis. The results showed that the score had a moderate predictive ability, with an area under the curve (AUC) for all score's components of 0.73 (95% CI 0.681–0.778). AUC for FOBAS > 7 and for FOBAS > 4 were 0.66 (95% CI 0.607–0.714) and 0.58 (95% CI 0.524–0.641), respectively (p -value < 0.001) (Fig. 3 & Table 3). Table 4 presents the true/false positive and true/false negative values for the low-risk group (1–3) and for the high-risk group (7–10). In this way, we demonstrated the score's ability to discriminate between the low-risk group that could be discharged from the ED and the high-risk group that would go through bronchoscopy.

Discussion

In this retrospective cohort study ($n = 412$), children with suspected FBA who were diagnosed with FBA on bronchoscopy were compared to those without FB on bronchoscopy according to history, physical examination, laboratory tests, and radiology findings at the emergency department. The study aimed to evaluate the effectiveness of FOBAS, a scoring system for predicting FBA in children. The results

showed that exposure to seeds/nuts, stridor, unilateral auscultatory findings (reduced breath sounds/wheezing), and suggestive findings on chest X-rays (unilateral hyperinflation/ atelectasis) were significant risk factors for FBA in children. However, choking episodes, sudden cough, and absence of fever and rhinorrhea did not reach statistical significance. Oxygen saturation, parameters of complete blood count, and C-reactive protein did not differ between the groups.

Detecting the presence of foreign body aspiration (FBA), especially in children, is a challenging task due to the lack of specific and sensitive clinical findings. Establishing a uniform decision-making algorithm for accurate diagnosis of FBA in children presenting at the ED for suspected FBA has been difficult as there is no global consensus on the management of these cases, and there are varying criteria for bronchoscopy across different centers. A missed FBA can result in long-term complications, thus requiring a high level of suspicion. However, bronchoscopy, an invasive procedure, carries inherent risks.

Over the last two decades, several scores for FBA were published, including Kadmon et al. [19], Janahi et al. [16], Castro et al. [20], and Fasseeh et al. [13]. However, these studies were retrospective and had relatively small cohort sizes (ranging from 109–300 children). Ozyuksel et al. [15] proposed a new scoring system for suspected FBA based on physical examination and radiological evaluation, which showed an AUC of 0.81 in a cohort of 720 patients. However, this proposed score has not been prospectively validated and is not widely used in clinical practice. Kadmon et al. [19] suggested a computerized scoring system with 21 score components based on the history, physical examination, and radiological findings of 150 patients. This score was later validated by Satfler et al. [14] on 100 patients, showing an AUC of 0.74. Recently, Lee et al. [21] published a meta-analysis that reviewed seven existing clinical scores for FBA in children and concluded that there are no current

Table 4 – True and false positive and negative values for the low-risk and high-risk FOBAS

	Positive FBA	Negative FBA	p-value	Total
FOBAS low risk (1–3)	$n = 36, 20.1\%$ (FP)	$n = 143, 79.9\%$ (TN)	<0.001	179
FOBAS high risk (7–10)	$n = 35, 68.6\%$ (TP)	$n = 16, 31.4\%$ (FN)	<0.001	51

models that can be recommended to guide clinical decision-making for FBA in children.

A comprehensive medical history is suggested, with an emphasis on exposure to seeds/nuts, a choking episode, and a sudden cough. Exposure to nuts or seeds has shown a significant association with FBA [16, 22–24]. However, the literature on choking episodes and acute sudden cough is inconsistent. In Janahi et al. [16], witnessed choking was the only anamnesis-dependent parameter included, alongside physical examination and radiological parameters. In contrast, Fasseeh et al. [13] and Cohen et al. [6] found them to be significant factors in the prediction of FBA. The retrospective nature of our study may explain why these components were not statistically significant in our study. However, we do believe they are essential in assessing the risk for FBA and if they were evaluated prospectively, with specific questions, and documentation, they probably would be significant. Therefore, we included those parameters, in a combination with the clinical judgment, as a part of our scoring system.

On physical examination, the presence of stridor, unilateral wheezing, or decreased air entry were significant indicators for the presence of FBA similar to the results of other studies such as Divarci et al. [7], Ozyuksel et al. [15], Janahi et al. [16] and Kadmon et al. [19]. However, the absence of fever and rhinorrhea did not show significance in our study and was not a part of the scoring system in other studies. Despite this, we decided to include fever and rhinorrhea in our score as we believe their presence may indicate an alternative diagnosis such as viral infection. Interestingly, fever and rhinorrhea were found to be twice as common in the negative FBA group, when compared to the positive group. However, due to the retrospective nature of our study, we acknowledge that documentation of fever and rhinorrhea may not have been consistent since they are often asked as ‘rule out’ questions and not always documented.

Chest x-rays are routinely performed in the pediatric ED when an FBA is suspected since it is an informative, readily available, and quick imaging modality. A pediatric radiologist interpreted all the chest X-rays and assigned them a score of either 0 (no FBA suspected) or 1 (suspected FBA) based on suggestive radiological findings. An x-ray suggestive of an FBA was highly significant ($p < 0.001$) and had a high probability of predicting the presence of FB.

In our study, there were no differences in white blood cell count and CRP between the groups, probably due to early diagnosis and removal, without the complication of chronic inflammation because of prolonged FBA [22, 25].

According to a univariable and multivariable logistic regression analysis that combined all the score components and was adjusted for demographic parameters such as age, sex, and ethnicity, we propose the FOBAS scoring system

as a good predictor for FBA in children, with a 1.73 higher chance for each additional point of the score and 3 times higher chance for each risk group. The combination of the score components is a stronger predictor for FBA in children than each parameter by itself.

One strength of our study is the relatively large sample size of more than 400 children who underwent flexible or rigid bronchoscopy for a definitive diagnosis of FBA. All included children underwent assessment in the ED, including medical history, vital signs, physical examination, blood work-up, and chest X-ray.

However, our study has a few limitations. Our main limitation is the retrospective nature, with some missing reported data in some patient files. This may have contributed to the lack of statistical significance in some medical history components, which were likely not documented properly. Another limitation is that our study population included only children who underwent flexible bronchoscopy for suspected FBA, potentially causing selection bias. However, our percentages of positive FBA (37.4% out of all bronchoscopies) were similar to previously reported percentages [6, 16], making our study population representative.

Conclusion

A combination of medical history, physical examination, and radiological findings were significantly associated with FBA in children. The FOBAS scoring system is a good predictor for FBA in children. Once prospectively validated, FOBAS can be used as a decision-making tool for the assessment and treatment of children with suspected FBA in the pediatric ED.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s00431-023-05095-w>.

Author contributions IGT contributed to the study's conception and design. Material preparation and data collection were performed by IR, SP, SA, MA, DG, ST, and AG. Statistical analysis was performed by YD. The first draft of the manuscript was written by IR and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability Raw data were generated at the Soroka University Medical Center. Derived Data supporting the findings of this study are available from the corresponding author (IGT) upon reasonable request.

Declarations

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Soroka University Medical Center (0290–19–SOR).

Competing interests The authors have no relevant financial or non-financial interests to disclose.

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