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New scoring system to predict foreign body aspiration in children

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ABSTRACT

Purpose: To propose a new scoring system to predict foreign body aspiration (FBA) in children.
Methods: Children who underwent bronchoscopy for FBA were evaluated for age, sex, history of aspiration, physical examination, radiological findings and results of bronchoscopy retrospectively. A new proposed FBA scoring including statements about history, physical and radiological findings were applied to all patients to define a total score. The results of each statement and total FBA score were compared according to bronchoscopy findings. The sensitivity and specificity of FBA score and cut-off values of total FBA score to predict positive cases were evaluated.
Results: Totally 720 patients with a male to female ratio of 227:133 were included. FBA was noted in 52.1% (n = 375) of cases. When the scoring system compared with the existence of foreign body (FB), the patient history had no statistical significance to predict positive cases ($p > 0.05$). The existence of FB was significantly associated with physical examination, radiological findings and total FBA score ($p < 0.001$). The revised scoring system without history parameters had range of total scores 0 to 5. The total scores were obtained by sum of physical findings and radiological parameters and the cut-off value of 2 had the highest diagnostic performance with sensitivity and specificity of 77.9% and 74.8% to predict FBA in children.
Conclusion: Our results suggest that the proposed scoring system can be utilized to predict FBA in children. The total score higher than 2 is predictive for FBA. Although, physical and radiologic findings are strong parameters for positive bronchoscopy, the history of FBA has no diagnostic utility.
Level of evidence: Level III (retrospective comparative study)
Study type: Diagnostic study

Foreign body aspiration (FBA) is one of the most common causes of accidental death in preschool and younger age children and frequently encountered between the ages of 1–3 years [1]. FBA has a variable clinical presentation ranging from asymptomatic state to a severe respiratory failure requiring urgent intervention. Symptoms mostly depend on the type, size and location of foreign body and the length of time it remains in the tracheobronchial tree. The diagnosis of FBA is made on clinical backgrounds, physical findings and radiological evaluations. Bronchoscopy is the most well-known technique for the diagnosis also the treatment [2–3].

Rigid bronchoscopy under general anesthesia is performed in the presence of clinical and radiological findings. In different series, foreign body could not be detected with rigid bronchoscopy in 16–57% of cases when done for possible FBA [4]. Righinni et al suggest that unnecessary bronchoscopy not only exposed the child to risks of anesthesia but also may have perioperative complications such as bronchospasm, desaturation, edema and bleeding [5]. Therefore, several studies were investigated the sensitivity and specificity of clinical findings, physical examination and radiologic investigations to reduce the rate of negative bronchoscopies. However, the sensitivity of each item is also variable ranging from 10 to 90% [6]. Kiyan et al reported a retrospective study to evaluate the sensitivity and specificity of clinical history, symptoms, physical examination findings and radiological findings. They found that sensitivity and specificity of each parameter were 90.5% and 24.1%, 97.8% and 7.4%, 96.4% and 46.3, and 71.7% and 74.1% respectively [7]. Although, similar results are commonly reported in the literature, many children undergo rigid bronchoscopy even with negative results because of severe long-term complications of missed FBA and lack of absolute diagnosis. Computed tomography scans are also suggested as useful diagnostic tools to decrease the rate of negative bronchoscopies [8]. Exposure to radiation in CT scan is also another concern and not applicable to all children with suspicion of FBA.

Janahi et al reported the key clinical and statistical significant predictors of FBA based on history, physical and radiologic parameters [9]. They also suggest a scoring system including history. In this study we proposed a new scoring system to predict FBA in children. To the best

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of our knowledge, this is the only scoring system for FBA evaluating the risk of aspiration according to the categorization of all parameters that used in diagnosis.

1. Methods

Patients who underwent rigid bronchoscopy with a presumptive diagnosis of FBA between 2009 and 2019 were included. Patient's clinical reports made by the pediatricians and the pediatric surgeons were evaluated for age, sex, history of aspiration, physical examination, radiological findings and results of bronchoscopy retrospectively. All statements of history of aspiration, physical examination and radiological findings were scored. These scores are the history parameters were no history (0), recurrent RTI (1), cough (2), sudden onset respiratory difficulty (3), respiratory difficulty during feeding (4) and witnessed aspiration (5). The physical parameters include normal physical findings (0), wheezing-stridor (1), decreased breath sounds on one side (2) and cyanosis-respiratory insufficiency (3). Radiologic parameters were normal chest x-ray (0), hyperinflation on one side (1), shift in mediastinum (2), foreign body in chest CT (3), and opaque foreign body in chest x-ray (4) (Table 1). While scoring the each parameter, we used the highest scores according to the sensitivity and specificity of parameters in previous studies. When scoring the patients, if one patient had more than one positive finding under the list of one statement, we gave the higher score in that statement. The FBA scores for history, physical and radiological findings were applied to all patients. We proposed the new scores of physical examination, new scores of the radiological findings and the total score by using above mentioned scores for using of the diagnosis of FBA.

1.1. Statistical methods

The Statistical Package for the Social Sciences version 23.0 for Windows (SPSS, Inc., Chicago, IL) was used for analysis of the data. ROC curve analysis was used to assess the diagnostic accuracy of each scoring system for history of aspiration, physical examination, radiological findings. The categorical regression analysis was used to obtain the new scoring system for prediction of presence and absence of FBA. The ordinal variables, which are physical examination score and radiological finding score, were included in the model as independent variables. The history score for detection of FBA was not included the regression model because area under the ROC curve of this score was not statistically significant (AUC: 0.498, $p>0.05$). The presence or absence of the FBA detected by bronchoscopy was given as the dependent variable in the regression model. The new scores of physical examination and radiological finding were obtained by using the standardized beta coefficients provided by the categorical regression analysis. Each independent variables in the model were weighted by using its standardized beta coefficient and then the scores were divided by the smallest coefficient and rounded to the nearest integer for the creating the new score of each independent variable and new physical examination score and new radiological finding score of each patient was calculated. Than the total score was obtained by summed up the new physical examination score and the new radiological finding score for each patient. Performance of the total score was evaluated by ROC curve analysis and sensitivity and specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated for each cut-off point. The cut-off value that gives the maximum of sensitivity plus specificity was accepted the best cut-off point for the total score. Pearson chi-square test was used to compare FBA groups for history of aspiration, physical examination and radiologic evaluation. Arithmetic mean, standard deviation, and minimum-maximum values were given as descriptive statistics for quantitative data. Qualitative data were summarized using frequency and percentages. The p value of less than 0.05 was considered to indicate a statistically significant.

The local ethical committee approved the study (2019/01-52, GO 19/39).

2. Results

Totally 720 patients who admitted with a presumptive diagnosis of FBA were enrolled. Mean age was 2.6 ± 2.5 years (4 months–17 years). Male to female ratio of patients was 227/133. The clinical symptoms were recurrent respiratory tract infections (rRTI), coughing, sudden onset respiratory deficiency, chocking during feeding, witnessed aspiration (Table 1). The most common finding in the history was respiratory difficulty during feeding (54%, $n=390$).

The physical examination findings ranged from normal findings to wheezing, stridor, decreased breath sounds on one side, cyanosis and severe respiratory difficulty (Table 1). The decreased breath sounds on one side was seen in 40% ($n=273$) of patients and assessed as the most common finding.

The statements of diagnostic parameters for FBA were compared according to bronchoscopy results. Table 1 shows the number and percent of statements for both positive and negative bronchoscopies. The score of history of aspiration statements was not statistically significant ($p=0.087$) and the score of the physical examination statements and the score of radiological evaluation statements were statistically

Table 1
Comparison of history of aspiration, physical examination and radiologic evaluation according to bronchoscopy findings for foreign body aspiration (FBA).

Statements of diagnostic parameters for FBA		Bronchoscopy findings		p
History of aspiration statements - (Score)		FBA + n (%)	FBA - n (%)	
No history	(0)	-	-	0.087
Recurrent RTI	(1)	15 (4.0)	23 (6.7)	
Cough	(2)	25 (6.7)	27 (7.8)	
Sudden onset respiratory difficulty8	(3)	15 (4.0)	18 (5.2)	
Respiratory difficulty during feeding	(4)	221 (58.9)	169 (49.0)	
Witnessed aspiration	(5)	99 (26.4)	108 (31.3)	
Physical examination statements - (Score)				
Normal findings	(0)	66 (17.6)	198 (57.4)	
Wheezing, stridor	(1)	89 (23.7)	88 (25.5)	<0.001
Decreased breath sounds on one side	(2)	216 (57.6)	58 (16.8)	
Cyanosis, respiratory insufficiency	(3)	4 (1.1)	1 (0.3)	
Radiological evaluation statements - (Score)				
Normal chest X-ray	(0)	85 (22.7)	256 (74.2)	<0.001
Hyperinflation on one side	(1)	235 (62.7)	79 (22.9)	
Shift in mediastinum	(2)	32 (8.5)	7 (2.0)	
FB in chest CT	(3)	7 (1.9)	3 (0.9)	
Opaque FB on chest X-ray	(4)	16 (4.3)	0 (0.0)	
Total		**375 (1.0)**	**345 (1.0)**	

Table 2
New scoring system to predict foreign body aspiration (FBA) for Physical examination and Radiological evaluation.

Statements of diagnostic parameters for FBA	New score
Physical examination	
Normal findings	0
Wheezing, stridor	1
Decreased breath sounds on one side	2
Cyanosis, respiratory insufficiency	2
AUC (p)	**0.754 (p<0.001)**
Radiological evaluation	
Normal chest X-ray	0
Hyperinflation on one side	1
Shift in mediastinum	2
FB in chest CT	3
Opaque FB on chest X-ray	3
AUC (p)	**0.766 (p<0.001)**

AUC: Area under the ROC curve

Table 3
Results of categorical regression analysis.

Dependent variable	ANOVA	Independent variables	Standardized beta coefficient	F	p
Presence or absence FBA	F = 70.891 P<0.001	Physical examination Radiological evaluation	0.29 0.38	54.047 100.666	<0.001 <0.001

Table 4
Diagnostic performances of the each cut off point of the total score.

Cut-off points of total score	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC (p) of the total score
1	91.2	48.4	65.8	83.5	
2	77.9	74.8	77.0	75.7	0.816
3	57.9	89.3	85.4	66.1	(p<0.001)
4	9.1	98.6	87.2	49.9	
5	3.2	99.7	92.3	48.7	

significant (p<0.001). When positive cases considered, the most common parameter for history was respiratory difficulty during feeding (58.9%), decreased breath sounds on one side in physiologic findings (57.6%) and hyperinflation on one side in radiologic parameters (62.7%). In radiologic evaluation, 74.2% of cases with normal x-rays had no FB in bronchoscopy.

All medical statements of the patients were scored according to this scoring system showed in Table 1. Then, diagnostic performance of these scores were compared with the gold standard (Bronchoscopy findings) by using the area under the ROC curve (AUC) (Table 2). There was no statistically significant of diagnostic performance of the history score according to AUC (AUC: 0.498, p>0.05) for detection of FBA. (Table 2). However the discriminating ability of other scores; physical examination score (AUC: 0.754, p = 0.018), radiological finding score (AUC: 0.766, p<0.001) were statistically significance (Table 2). Then we performed the categorical regression analysis by using above the scores to obtain the new scores for physical examination and radiological finding. The history score was not entered in the categorical regression analysis because both the result of the comparison with bronchoscopy findings (p<0.087) and diagnostic performance (AUC: 0.498, p>0.05) was not statistically significance.

Table 3 shows the results of the categorical regression analysis. According to Table 3, categorical regression model was statistically significant (F = 70.891, P<0.001) and standardized beta coefficient of the independent variables, physical examination score and radiological evaluation score were statistically significant (p<0.001). After obtaining the regression model, Each diagnostic score was weighted by using its standardized beta coefficient and then the scores were divided by the smallest coefficient and rounded to the nearest integer for the creating the new score of each independent variable. The obtained new scores of the physical examination score and radiological evaluation were shown in the Table 2. After, the total score for each patient was calculated by summing up the new scores of the physical examination score and radiological evaluation. The diagnostic performance values of the each cut off point of the total score are also given in Table 4. The diagnostic performance of the total score was higher than both physical examination and radiological evaluation and statistically significant (AUC = 0.816, p<0.001) .The best cut off value for total score was obtained as 2. This cut off point has a sensitivity of 77.9%, and specificity of 74.8% (Table 4).

3. Discussion

We proposed the first scoring system to predict FBA in children. FBA is a life-threatening emergency in children that may require urgent bronchoscopy. It is common under 4 year of age and boys are more prone to develop FBA [10]. The mean age of our patients was 2.6 years and 83.5% of our cases are younger than 4 years of age. Also, boys are more common than girls (67.5% vs 32.5%) among our cases. Although, we evaluated the history of aspiration, physical findings and radiologic tests in detail, we still have 47.1% of negative bronchoscopies.

The use of history of aspiration, clinical and physical examination findings and radiological investigations to have an accurate diagnosis is controversial. The recent studies evaluate the use of these preoperative evaluations to define FBA and avoid negative bronchoscopies. There may be normal physical and clinical findings, no history of aspiration and normal radiologic evaluations in children with FBA. Thus, it has been difficult to consistently establish diagnosis without bronchoscopy. The rigid bronchoscopy has its own risks including bronchospasm, airway edema, bleeding and desaturation. And, children may expose the risk of general anesthesia. Therefore, negative bronchoscopy rates should be decreased. Higher rates up to 57% are still reported [4]. Current efforts are focused on to predict the positive FBA cases by using the history, clinical and physical findings and radiology.

The history of FBA is considered as an important clue to predict FBA. Several authors consider positive history such as witnessed aspiration as an indication of rigid bronchoscopy in children with respiratory symptoms. Janahi et al found that witnessed choking and noisy breathing are significant predictors of FBA [9]. Kiyan et al reported that clinical history had 90.1% of sensitivity and 24.1% specificity in cases with FBA [7]. On the other hand, some studies show no correlation between witnessed aspiration and FBA [11–12]. In our study, the rate of witnessed aspiration is noted 31.3% of cases without FBA and 26.4% of cases with FBA. Cough and choking is reported as the most common findings in other series [13]. Different from the other studies, respiratory difficulty during feeding (54%, n = 390) was common among our patients. When considering the all history parameters, none of them showed statistical significance to predict positive cases (p>0.05). The diversity of results may be related with inaccuracy of parent's reported history. We suggest that high rate of negative bronchoscopies in our series may be due to use of aspiration history as an absolute indication for bronchoscopy. Therefore, an accurate diagnosis can be obtained by a holistic approach not only with history but also considering all parameters (physical findings, radiologic evaluations and total FBA score). Thus, we revised our scoring system after omitting the history scores.

Wheezing and decreased breath sound on one site is the most common physical findings in children with FBA. The sensitivity of physical findings reported as 94.6% and specificity was 46.4% in one series [7]. New onset wheezing, recurrent and/or persistent wheezing is also significantly predictive to diagnose FBA [9]. In 57.4% of our patients with negative bronchoscopy had normal physical findings. However, 57.6% of cases with FBA had decreased breath sounds on auscultation. The physical findings had statistically significant contribution to predict FBA with specificity of 86% and sensitivity of 53%.

Plain X-rays are common diagnostic tools to diagnose FBA. Unilateral and/or localized hyperlucency, shift in mediastinum and opaque foreign bodies can be seen in positive cases. The sensitivity and specificity of chest X-rays was reported as 62% and 57% respectively [14]. Low dose CT scans and virtual bronchoscopy can be used in the diagnosis [15]. Some studies suggest that use of CT scans decreases the rate of negative bronchoscopies. In our series, 74.2% of cases with negative bronchoscopy had normal chest X-ray findings and most common finding

suggesting a FB was hyperinflation on one side (62.7%). Our results were comparable with the previous studies [16]. The radiologic findings have sensitivity and specificity of 77% and 74% [17].

The rates of positive bronchoscopy reported in the literature ranges from 30% to 90% [1]. The positive bronchoscopy rate was 52.1% in our study. Therefore, we needed to propose a new scoring system to decrease negative bronchoscopy rates. According to our results, although the history had no statistical significance of AUC, the physical examination parameters and especially radiological findings and total FBA scores have statistically significance for diagnosis of FBA in children ($p<0.05$). After, excluding history parameters, we found that cut-off value for total score was 2 with a sensitivity and specificity of 77.9% and 74.8% respectively. The retrospective design is the most important limitation of our study. A prospective study in the light of these findings is subject of our future studies. We suggest that new scoring system proposed in this study is simple to perform, easy to assess at emergency department by both pediatricians and pediatric surgeons and reliable tool to predict FBA. Patients with total scores less than 2 may require further diagnostic approach such as CT scans to reduce the rate of negative bronchoscopies. Also, patients with only positive history of aspiration and without other findings should require detailed evaluation before underwent urgent bronchoscopy.

In conclusion, the results of this study suggest that the proposed scoring system can be utilized to predict FBA in children. The total scores equal and higher than 2 is highly predictive for FBA. Although, radiologic findings and physical examination have strong parameters for positive bronchoscopy, the history of FBA has no diagnostic utility.

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