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Foreign body ingestion in children: Definition of a nomogram to predict surgical or endoscopic intervention

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ABSTRACT

Background and aims: Foreign body ingestion (FBI) in children requires early identification to prevent adverse outcomes and may necessitate endoscopic or surgical intervention. This study aims to develop a nomogram that identifies children who require urgent surgical or endoscopic intervention by using the patient's medical history and clinical parameters collected at admission.
Methods: This study is a retrospective review (01/2015–12/2020) of a multicenter case series of children admitted for FBI. Data from 5864 records from 24 hospitals in Italy were analyzed. Logistic regression models were used to establish the probability of requiring surgical or endoscopic intervention based on patient history and clinical characteristics. The nomogram representing the results from the multivariable model was reported to examine the propensity for surgery/endoscopy.
Results: The study identified a significant association between intervention and various factors, including type of foreign body (blunt: reference category, disk battery (odds ratio OR:4.89), food bolus (OR:1.88), magnets (OR:2.61), sharp-pointed (OR:1.65), unknown (OR:1.02)), pre-existing diseases or conditions (OR 3.42), drooling (OR 10.91), dysphagia (OR 5.58), vomiting (OR 3.30), retrosternal pain (OR 5.59), abdominal pain (OR 1.58), hematemesis (OR 2.82), food refusal/poor feeding (OR 2.99), and unexplained crying (OR 2.01). The multivariable regression model showed good calibration and discrimination ability, with an area under the ROC curve of 0.77.
Conclusions: This study developed the first nomogram to predict the probability of the need for surgical or endoscopic intervention in children with FBI, based on the information collected at admission. The nomogram will aid clinicians in identifying children who require early intervention to prevent adverse outcomes.

Introduction

Foreign body ingestion (FBI) in children is a common and challenging clinical scenario in the pediatric emergency department (ED) [1,2].

The American Association of Poison Control Centers reported approximately 80,000 calls in 2018 [3]. In the past 13 years, the annual rate of FBI in children has increased by 80% [4], and since 1995 in the US, the annual rate of consultation in EDs for FBI in children <6 years has increased by 92% [5]. During the coronavirus (COVID) pandemic in 2020, the daily ingestion rate increased compared to pre-pandemic levels [6]. While many ingested foreign bodies typically pass through the gastrointestinal tract without harm, adverse events can still occur [7,8]. In particular, button batteries pose a serious risk, leading to significant complications in 0.8% of cases and even death in 0.15%, primarily among children <4 years old [9]. Additionally, there has been a recent rise in the annual rate of adverse events associated with sharp objects, magnets, batteries, and caustic agents [4].

The significant number of ED admissions and interventions related to FBI have a considerable impact on the healthcare system [6,10]. Hence, it is crucial to prioritize the identification of children requiring urgent intervention. This process should not be hindered by limited hospital resources, such as overcrowding in pediatric EDs or lack of staff experience, as reported in recent literature [1,11,12].

Current guidelines for managing FBI lack clear information on identifying and managing young patients who may be at risk of adverse events [1,10,13].

Determining the need for endoscopic examination or surgery can be challenging, even with a detailed clinical history encompassing age, type, and size of ingested FB, presence or absence of symptoms, and time elapsed since ingestion and last meal. In the absence of identifiable FB location, imaging techniques such as chest X-ray, X-ray contrast study, CT scans are necessary to guide treatment [1,10,13]. However, not all pediatric EDs are equipped with all essential services, including radiology, on a 24/7 basis. The time-consuming process of determining which objects can safely pass through the gastrointestinal tract further complicates the need for timely endoscopic intervention [1,10,13]. To address this issue, scoring systems have gained traction in identifying patients at risk of deterioration requiring endoscopy [13–15]. However, currently, no scoring system enables the selection of children who urgently require gastrointestinal endoscopic removal or surgery in cases of FBI.

This study aims to analyze a substantial multicenter case series of children admitted to EDs for FBI and identify predictive factors for the need for endoscopy and surgery. By combining these clinical factors, we aim to develop a nomogram that can effectively identify children who require timely and appropriate utilization of endoscopy or surgery.

Patients and methods

Patient selection

A structured retrospective chart review that covered the period January 2015 to December 2020, was conducted in 24 hospitals in Italy; all pediatric ED visits and in-patient admissions related to FBI and food bolus impaction were registered.

The study focused on collecting information through the System of Statistical Classification of Diseases and Related Health Problems (https://apps.who.int/iris/handle/10665/246208) by utilizing specific codes (T18.x) corresponding to FB in the digestive tract. Instances of FBs in the mouth (T18.0) and the anus and rectum (T18.5) were not included in the analysis. Exclusion criteria encompassed patients with: a) unwitnessed FBI without symptoms or imaging evidence of FB, b) incomplete data, or c) unknown therapeutic management.

This study adheres to the ethical principles outlined in the Declaration of Helsinki and obtained approval from the Sapienza University Ethics Committee (Approval No 6505/2022).

Data collection

Data collection was conducted systematically by reviewing medical records of all enrolled patients. The following information was retrieved: patient demographic information (age, gender), medical comorbidities (e.g., eosinophilic esophagitis (EoE), reflux esophagitis), associated surgical pathologies (e.g., esophageal atresia, post-anastomotic stricture, achalasia), neuropsychiatric disorders, presence/absence/type of symptoms (e.g. vomiting, food aversion, respiratory symptoms, dysphagia, drooling, and unexplained crying), type of FB (blunt, sharp-pointed, disk batteries, magnets, food bolus or unknown FB) and therapeutic management approach (none, endoscopy, surgery or unknown).

Statistical analysis

Statistical analysis was conducted to assess the association between the available features at the time of presentation in the ED and the intervention received. The following variables were included in the analysis: intervention type (e.g., surgical/endoscopic intervention, no intervention), gender, age group/division (< 1 year, 1-5 years, 6-10 years, and 11-18 years), foreign body type (blunt, disk battery, food bolus, magnets, sharp-pointed, unknown), presence or absence of previous medical conditions, and presence or absence of symptoms (such as drooling, dysphagia, vomiting, pharyngodynia, retrosternal pain, abdominal pain, respiratory symptoms, odynophagia, hematemesis, food refusal/poor feeding, and unexplained crying).

All the variables mentioned above were presented as counts and percentages. Logistic regression models were used to assess the association between patient characteristics and intervention. The response variable was intervention (1 = surgical/endoscopic intervention, 0 = no intervention performed) and a logit link was used. Univariate logistic regression models were employed to examine the association with each characteristic. A multivariable model was created using a backward selection procedure to exclude variables that did not significantly contribute to the model. This allowed for the evaluation of the combined effect of patient features on the likelihood of receiving surgery/endoscopy or no intervention. Gender and age were considered potential confounding variables and were retained in the model.

For each regression model (univariate and multivariable), the association was assessed using a likelihood-ratio (LR) test, which follows a chi-square distribution. The strength of association was measured in terms of odds ratio (OR) and 95% confidence interval (CI). Additionally, a nomogram representing the results from the multivariable model was provided to further examine the propensity for surgery/endoscopy.

The predictive accuracy of the multivariable model was evaluated by examining calibration and discrimination. Calibration refers to the agreement between predicted probabilities (in this study: probabilities of surgical/endoscopic intervention) and actual probabilities, while discrimination assesses the model's ability to distinguish patients who received intervention from those who did not. Calibration was evaluated using a calibration curve, and discrimination was evaluated using Harrell's C-index, which is equivalent to the area under the ROC curve (AUROC). Bootstrap methods with 1000 bootstrap samples were employed for both calibration and discrimination assessment [16,17].

The statistical analysis was performed using R software, version 4.2.2 (R Foundation for Statistical Computing), with the rms packages (Harrell Jr FE (2022).rms: Regression Modeling Strategies_. R package version 6.3-0 https://CRAN.R-project.org/package=rms) added.

Results

The preliminary case series consisted of 6014 children, and the analysis was conducted on a subset of 5864 records, providing aggregate information. Of the 5864 patients included in the study, 1410 (24%) underwent an endoscopic examination, 24 (0.5%) received surgery, and the remaining 4430 (75.5%) did not receive any intervention. Table 1 presents the characteristics of the patients; a minority of patients had pre-existing medical conditions (Supplementary table 1). No deaths were recorded.

Based on these characteristics, the following observations were made: a) the majority of ED visits involved children aged 2-4 years (2599 patients; 44.0%), b) most of FB were blunt objects (3027 patients; 52.0%), and c) a large proportion of patients were asymptomatic (4471 patients; 76.2%).

Association between patient characteristics at presentation and intervention

Univariate analysis revealed a significant association with intervention type and several patient characteristics, including age, foreign body type, pre-existing medical conditions, and multiple symptoms (specifically drooling, dysphagia, vomiting, retrosternal pain, odynophagia, food refusal, and unexplained crying). Patients who ingested food bolus or disk batteries had a higher likelihood of undergoing surgical/endoscopic intervention compared to those who ingested blunt objects (OR = 13.0, 95% CI = 9.6 to 17.8; and OR = 3.3, 95%CI = 2.6 to 4.0, respectively). The propensity for intervention in patients who ingested magnets, sharp-pointed objects, and unknown object types was only slightly higher or similar to that for blunt objects (OR = 1.9, 1.2, and 1.10, respectively). Patients with pre-existing medical conditions had a higher likelihood of intervention compared to those without (OR = 5.3, 95% CI = 4.2 to 6.6). Among different age groups, patients aged 11-18 exhibited a slightly higher likelihood of intervention compared to the reference category (< 1 year; OR = 1.5, 95% CI = 1.1 to 2.2).

In terms of symptoms, the highest likelihood of surgical/endoscopic intervention was observed in patients with drooling (OR = 13.9, 95% CI = 11.1 to 17.4), dysphagia (OR = 10.6, 95% CI = 8.0 to 14.3), food refusal (OR = 6.5, 95% CI = 4.3 to 9.8) and retrosternal pain (OR = 5.9, 95%CI = 4.3 to 8.3) (Table 2).

In the multivariable analysis, all variables, except age, pharyngodynia, respiratory symptoms, and odynophagia, were significantly associated with the intervention. The ORs obtained from the multivariate analysis aligned with those estimated from univariate regression models. Notably, the multivariate OR for drooling, although slightly lower (OR = 10.9 vs. OR = 13.9) still indicated a strong likelihood of surgical/endoscopic intervention. However, for food bolus ingestion, the propensity for intervention was only slightly higher (OR = 1.9 vs. 13.0). In summary, patients with the following characteristics are more likely to undergo intervention: females aged 11 to 18 years who have ingested disk batteries, magnets or food bolus, and present at least one symptom, including drooling, dysphagia, vomiting, retrosternal pain, abdominal pain, hematemesis, food refusal or unexplained crying (Table 2).

To facilitate the assessment of how specific characteristics contribute to a higher or lower likelihood of intervention, a nomogram was created (Fig. 1).

Assessment of predicted performance of the multivariable model

The calibration graph, depicted in Fig. 2, compares the estimated probabilities of the performed interventions with the empirical probabilities. The solid line represents the calibration curve, which was calculated using bootstrap methods to provide a practical and robust approach to estimate the variability and uncertainty associated with a model parameter estimation.

The graph demonstrates that the calibration curve closely aligns with the "ideal" scenario (represented by the dashed line), where the estimated probabilities perfectly match the actual probabilities. This indicates that the multivariable regression model exhibits

Table 1
Characteristics of 5864 children under study.

	no intervention (*N* = 4430)	surgical/endoscopic intervention (*N* = 1434)	All (*N* = 5864)
Gender			
Female	1919 (43.0%)	629 (44.0%)	2548 (43.0%)
Male	2511 (57.0%)	805 (56.0%)	3316 (57.0%)
Age(years)	159 (3.6%)	57 (4.0%)	216 (3.7%)
< 1	624 (14.0%)	201 (14.0%)	825 (14.0%)
1	788 (18.0%)	234 (16.0%)	1022 (17.0%)
2	679 (15.0%)	218 (15.0%)	897 (15.0%)
3	543 (12.0%)	137 (9.6%)	680 (12.0%)
4	537 (12.0%)	157 (11.0%)	694 (12.0%)
5	762 (17.0%)	243 (17.0%)	1005 (17.0%)
6–10	338 (7.6%)	187 (13.0%)	525 (9.0%)
11–18			
Pre-existing diseases	4304 (97.0%)	1243 (87.0%)	5547 (95.0%)
N	126 (2.8%)	191 (13.0%)	317 (5.4%)
Y			
Foreign body type			
Disk battery	236 (5.3%)	185 (13.0%)	421 (7.2%)
Food bolus	59 (1.3%)	184 (13.0%)	243 (4.1%)
Magnets	39 (0.9%)	18 (1.3%)	57 (1.0%)
Sharp-pointed objects	813 (18.0%)	237 (17.0%)	1050 (18.0%)
Blunt objects	2440 (55.0%)	587 (41.0%)	3027 (52.0%)
Unknown	843 (19.0%)	223 (16.0%)	1066 (18.0%)
Symptoms			
drooling	107 (2.4%)	366 (26.0%)	473 (8.1%)
dysphagia	64 (1.4%)	193 (13.0%)	257 (4.4%)
vomiting	188 (4.2%)	212 (15.0%)	400 (6.8%)
pharyngodynia	60 (1.4%)	32 (2.2%)	92 (1.6%)
retrosternal pain	57 (1.0%)	103 (7.0%)	160 (2.7%)
abdominal pain	111 (2.5%)	59 (4.1%)	170 (2.9%)
respiratory symptoms	196 (4.4%)	77 (5.4%)	117 (2.0%)
odynophagia	63 (1.4%)	54 (3.8%)	273 (4.7%)
hematemesis	9 (0.2%)	12 (0.8%)	21 (0.4%)
food refusal/poor feeding	36 (0.8%)	72 (5.0%)	108 (1.8%)
unexplained crying	38 (0.9%)	41 (2.9%)	79 (1.3%)
Number of symptoms			
0	3810 (86.0%)	661 (46.1%)	4471 (76.2%)
1	474 (10.7%)	519 (36.2%)	993 (17.0%)
> 1	146 (3.3%)	254(17.7%)	400 (6.8%)

good calibration, accurately predicting the likelihood of interventions. Furthermore, the estimated AUROC was 0.775, with a 95% CI of 0.760 to 0.790, as shown in Fig. 3. This AUROC value indicates that the model has good discrimination ability, effectively distinguishing between patients who require interventions and those who do not. To provide a user-friendly tool for estimating the probability of intervention, we developed a nomogram. The nomogram comprises calibrated scales or axes that represent the variables used in the estimation process [18]. By locating a patient's position on the horizontal scale for each variable and assigning corresponding point values according to the points scale (top axis), the points are then summed across all variables. The total points correspond to an estimated probability value for intervention (endoscopy/surgery).

Discussion

This study conducted a comprehensive analysis of a large multicenter case series involving children admitted to EDs due to FBI. The objective was to identify factors that could assist in determining the necessity for endoscopy and surgery. Additionally, a nomogram was developed to aid in the decision -making process for managing these patients within EDs. It is important to note that this scoring system is not intended to replace imaging, which plays a crucial role in identifying and locating foreign bodies, thereby facilitating the selection of the most appropriate therapeutic approach [1,10,13]. Instead, the nomogram serves as a valuable tool that can support pediatricians and general doctors working in EDs, enabling them to make informed medical decisions when confronted with cases of FBI in children. Furthermore, the nomogram enhances communication between healthcare professionals, such as radiologists and pediatric surgeons/endoscopists, involved in the care of these patients.

In our nomogram, symptoms play a crucial role in guiding decision-making compared to other variables. In our case series, a quarter of enrolled patients exhibited symptoms, with vomiting and drooling being the most frequently reported ones, which aligns with findings in the existing literature [19–21]. Symptoms associated with FBI can manifest as gastrointestinal symptoms (such as vomiting, drooling, dysphagia, odynophagia, globus sensation, etc.) or respiratory symptoms (such as cough, stridor, and choking), although the latter are relatively rare [19,20]. It has been previously observed that there is an association between symptoms and FB location, implying a potential correlation between symptoms and treatment outcomes [19]. Notably, not all symptoms carry the same weight in our scoring system. Symptoms related to an esophageal location contribute the highest number of points. Specifically, drooling, dysphagia and retrosternal pain are associated with a 50%, 30%, and 30% increased risk of intervention, respectively, compared to patients who do not exhibit these symptoms. This finding is consistent with established guidelines that recommend prompt endoscopic removal of the FB when esophageal obstruction and the inability to control secretions are present [1,10,13]. Other symptoms, such as vomiting, food refusal,

Table 2
Univariate and multivariate ORs of surgical/endoscopic intervention

Features	Outcomes:	Univariate		Multivariate	
	n/N (%)	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Sex					
Female	629/2548 (24.7%)	Reference	0.717	Reference	0.044
Male	805/3316 (24.3%)	0.97 (0.87, 1.10)		0.87 (0.75, 1.00)	
Age (years)					
< 1	57/216 (26.4%)	Reference	< 0.001	Reference	0.5437
1	201/825 (24.4%)	0.90 (0.64, 1.27)		0.93 (0.63, 1.41)	
2	234/1022 (22.9%)	0.83 (0.59, 1.17)		1.14 (0.77, 1.70)	
3	218/897 (24.3%)	0.90 (0.64, 1.26)		1.15 (0.78, 1.72)	
4	137/680 (20.9%)	0.70 (0.49, 1.01)		0.93 (0.62, 1.42)	
5	157/694 (20.1%)	0.82 (0.58, 1.16)		1.03 (0.69, 1.57)	
6–10	243/1005 (24.2%)	0.89 (0.64, 1.25)		1.04 (0.70, 1.57)	
11–18	187/525 (35.6%)	1.54 (1.09, 2.21)		1.18 (0.78, 1.82)	
Foreign body type					
Blunt		Reference	< 0.001	Reference	< 0.001
Disk battery	587/3027 (19.4%)	3.26 (2.63, 4.03)		4.89 (3.89, 6.16)	
Food bolus	185/421 (43.9%)	12.96 (9.60, 17.75)		1.88 (1.28, 2.78)	
Magnets	184/243 (75.7%)	1.92 (1.07, 3.33)		2.61 (1.40, 4.66)	
Sharp-pointed	18/57 (31.6%)	1.21 (1.02, 1.44)		1.65 (1.36, 1.99)	
Unknown	237/1050 (22.6%)	1.10 (0.92, 1.31)		1.02 (0.84, 1.24)	
	223/1066 (20.9%)				
Pre-existing conditions					
No	1243/5547 (22.4%)	Reference	< 0.001	Reference	< 0.001
Yes	137/192 (60.3%)	5.25 (4.16, 6.64)		3.42 (2.57, 4.53)	
Drooling					
No	1068/5391 (19.8%)	Reference	< 0.001	Reference	< 0.001
Yes	366/473 (77.4%)	13.85 (11.09, 17.42)		10.91(8.47,14.1)	
Dysphagia					
No	1241/5607 (22.1%)	Reference	< 0.001	Reference	< 0.001
Yes	193/257 (75.1%)	10.61 (7.99, 14.27)		5.58 (3.91, 8.00)	
Vomiting					
No	1222/5464 (22.4%)	Reference	< 0.001	Reference	< 0.001
Yes	212/400 (53.0%)	3.91 (3.19, 4.81)		3.30 (2.56, 4.24)	
Pharyngodynia					
No	1402/5772 (24.3%)	Reference	0.022	–	–
Yes	32/92 (34.8%)	1.66 (1.07, 2.54)			
Retrosternal pain					
No	1331/5704 (23.3%)	Reference	< 0.001	Reference	< 0.001
Yes	103/160 (64.4%)	5.94 (4.29, 8.30)		5.59 (3.81, 8.22)	
Abdominal pain					
No	1375/5694 (24.1%)	Reference	0.002	Reference	0.015
Yes	59/170 (34.7%)	1.67 (1.20, 2.29)		1.58 (1.08, 2.28)	
Respiratory symptoms					
No	1357/5591 (24.3%)	Reference	0.140	Reference	0.120
Yes	77/273 (28.2%)	1.23 (0.93, 1.60)		0.76 (0.53, 1.07)	
Odynophagia					
No	1380/5747 (24.0%)	Reference	< 0.001	–	–
Yes	54/117 (46.2%)	2.71 (1.87, 3.92)			
Hematemesis					
No	1422/5843 (24.3%)	Reference	0.0013	Reference	0.043
Yes	12/21 (57.1%)	4.15 (1.75, 10.17)		2.82 (1.02, 7.76)	
Food refusal/poor feeding					
No	1362/5756 (23.7%)	Reference	< 0.001	Reference	< 0.001
Yes	72/108 (66.7%)	6.45 (4.34, 9.77)		2.99 (1.80, 4.96)	
Unexplained crying					
No	1393/5785 (24.1%)	Reference	< 0.001	Reference	0.017
Yes	41/79 (51.9%)	3.40 (2.18, 5.33)		2.01 (1.12, 3.56)	

unexplained crying, hematemesis, and abdominal pain, except for respiratory symptoms, contribute to a 10% to 20% increased risk of intervention.

The findings of this study hold significant importance as decision-making in EDs can be challenging, even for experienced pediatricians. Currently, decisions are based on individual medical history characteristics and clinical parameters collected upon admission, including the presence of clinical symptoms, related pre-existing gastro-intestinal conditions, and type of FB.

Our nomogram provides valuable insights into the decision-making process. For instance, let's consider a 4-year-old boy without any points for age, indicating his age group is not associated with increased intervention risk. If he is asymptomatic, he would receive 10 points, indicating a lower likelihood of intervention. Additionally, if he does not have any pre-existing conditions, he would receive 0 points, indicating a lower intervention risk associated with pre-existing conditions. Assuming he has ingested a FB, his score would range from 10 (unknown/blunt FB) to 65 (button battery ingestion), with an estimated probability of surgical/endoscopic intervention ranging from 10% to 30%. However, if the same boy experiences drooling, the likelihood of intervention increases significantly, ranging from 50% to 80%, corresponding to a

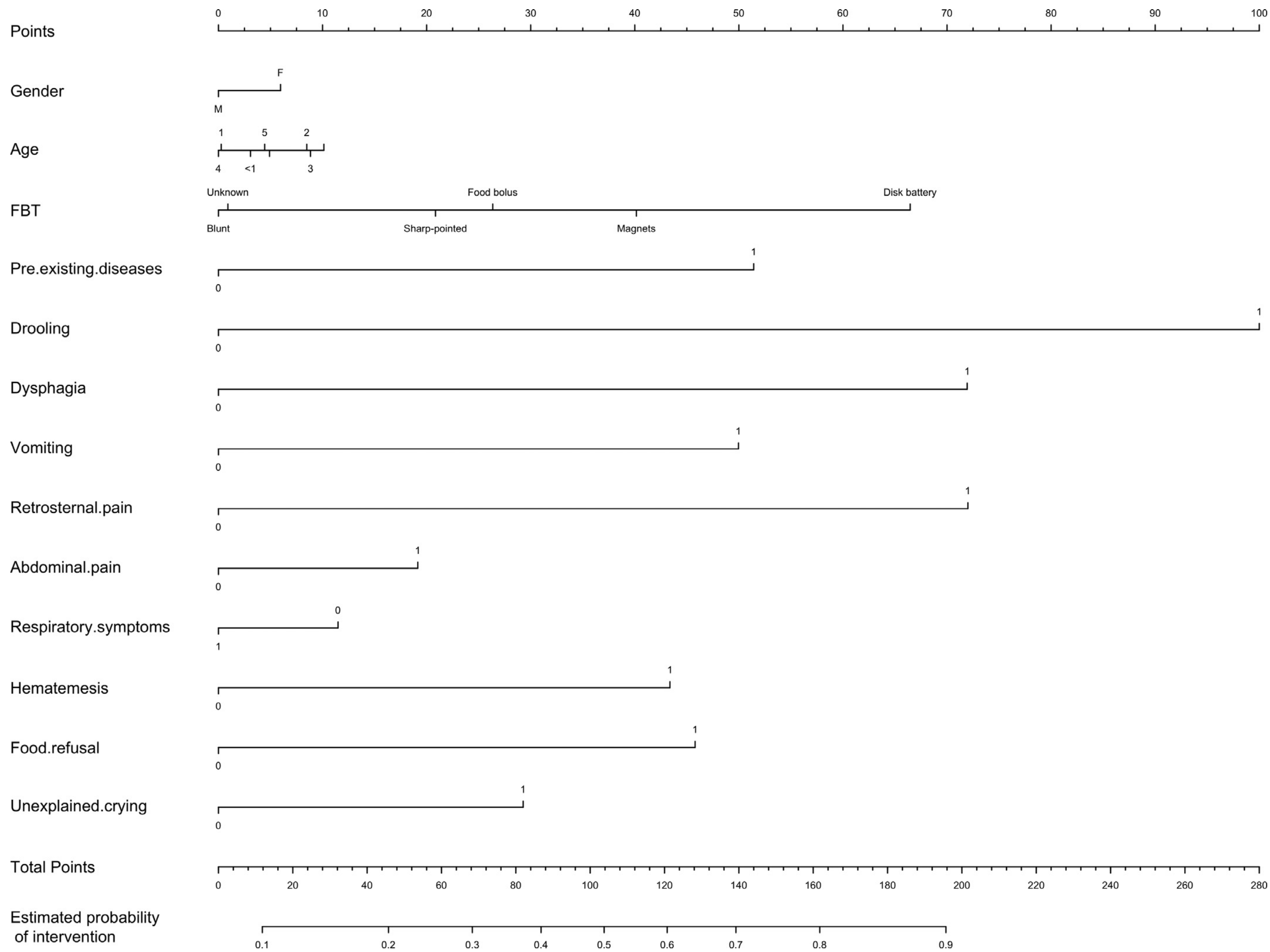

Fig. 1. Nomogram for calculating the probability of undergoing surgical/endoscopic intervention based on the multivariable logistic regression model developed in this work. The nomogram is used by first locating a patient's position for each variable on its horizontal scale. Then, a point value is assigned according to the points scale (top axis) and summed for all variables. Total points correspond to a probability value for undergoing surgical/endoscopic intervention. As an example: a) A 5-year-old female ingested a button buttery. She has an uneventful medical history, and she develops vomit. The estimated probability of intervention is 0.69 (95% CI: 0.60; 0.77). b) A 2-year-old healthy male ingested a coin of unknown diameter. He has no symptoms. The estimated probability of intervention is 0.12 (95% CI: 0.09; 0.15).

score ranging from 110 to 175. Furthermore, if the child also complains of vomiting, the risk of intervention escalates to 80%-to over 90%.

Asymptomatic children constitute the majority of admissions to the ED for FBI, as demonstrated in this study and previous research (68%) [19]. This highlights the potential challenge for pediatricians in managing cases where no symptoms are present, even when the ingested object is considered highly dangerous. For instance, applying our nomogram to an asymptomatic male who has ingested multiple magnets would yield a conditional probability of approximately 0.2 for undergoing endoscopic removal and laparotomy/laparoscopy. A similar low risk of intervention was recently reported by Huang et al. in a study involving children, where all symptomatic patients underwent surgical interventions while asymptomatic individuals (5 out of 6) received supportive care only [22]. However, despite the low probability of intervention indicated by the nomogram, early consultation with a pediatric surgeon is still recommended due to the potential risks associated with ingesting multiple magnets [1,10,13]. Actually the strong attraction of magnets can lead to serious complications such as ischemia, perforation, fistula, or volvulus of the bowel wall; in particular approximately 15% of multiple gastrointestinal perforations or obstruction in children are attributed to the ingestion of multiple magnetic beads, even in the absence of symptoms [1,10,13,23]. It is no wonder therefore that current guidelines emphasize the urgency of endoscopic removal [1,10,13].

Our nomogram could also serve a valuable tool for screening asymptomatic patients by considering other clinical factors, including the patient's previous medical history. It is important to note that most children who ingest a FB are healthy; in such cases, endoscopic or surgical removal occurs in approximately 21% of cases [1,10,13]. However, the rates if intervention increase when there are pre-existing related conditions such as gastrointestinal pathologies, esophageal atresia, rings, webs, achalasia, or eosinophilic esophagitis [24–26]. Esophageal food or FB impaction following repair of esophageal atresia/tracheoesophageal fistula is relatively common, affecting nearly 15% of patients and recurring in half of the reported cases [26,27]. Eosinophilic esophagitis (EoE) is another frequent cause of recurrent esophageal food bolus impaction [25]. Additionally, it is essential to consider neuropsychiatric disorders, as an association between FBI and these disorders has been reported [28]. Therefore, a comprehensive assessment of

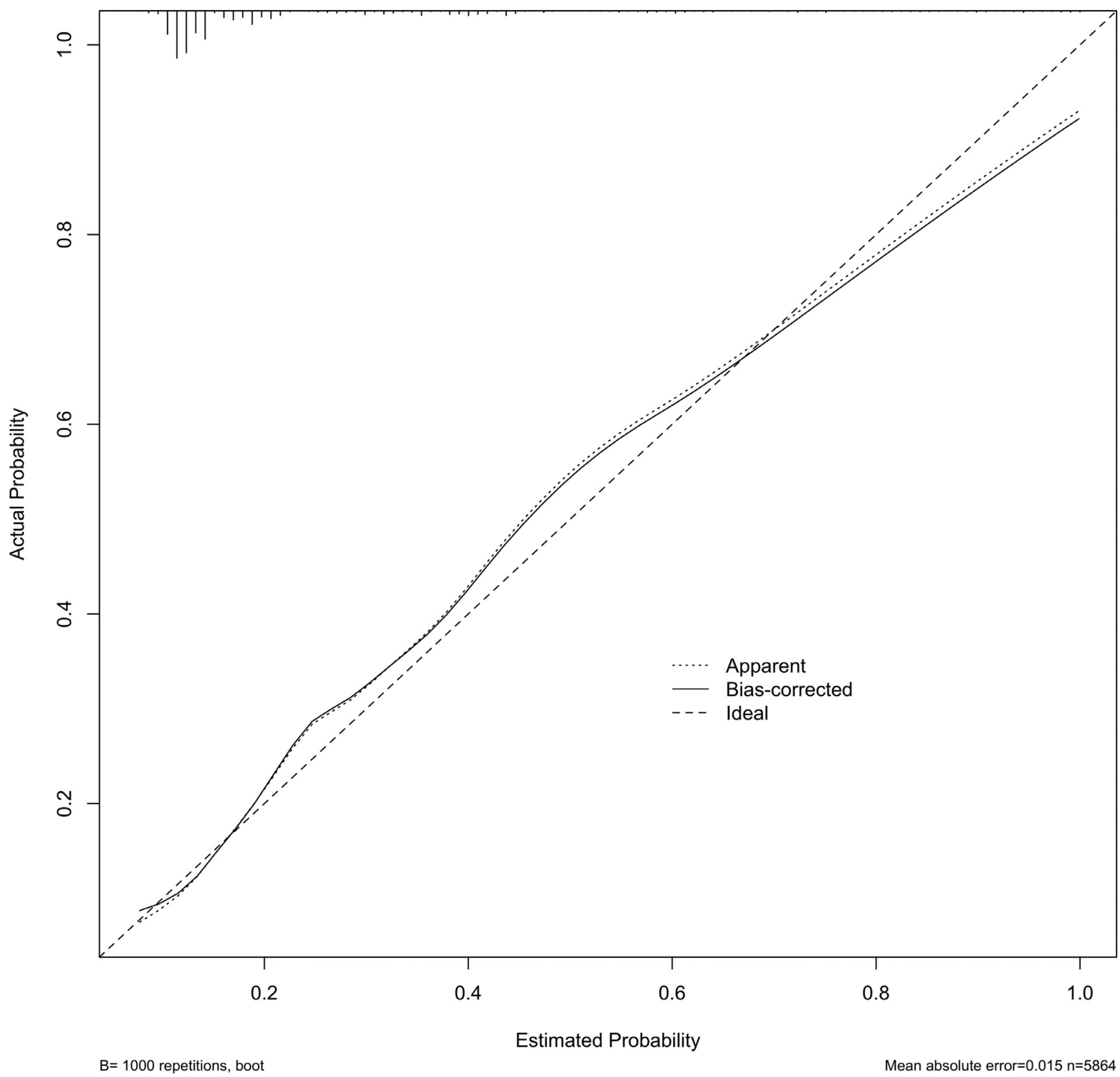

Fig. 2. Calibration graph for the estimated probability of undergoing surgical/endoscopic intervention.

the patient's medical history can provide valuable insights for decision-making in managing FBI cases.

Approximately 25% of healthy children and 60% of patients with pre-existing conditions undergo endoscopic or surgical procedures for FBI. In our study, we found that the presence of a related pathology increases the risk of surgical or endoscopic removal by 20% to 30% compared to those without any pre-existing medical condition.

The type of ingested FB is another key factor to consider. We examined all major categories (blunt, sharp-pointed, disk batteries, magnets, food bolus), including cases where the type of FB was unknown (18% of cases). Blunt FBs accounted for the majority (52% of events) and are commonly managed conservatively, particularly if they are small and have passed the pyloric sphincter [29]. Therefore, the presence of blunt FB is associated with the lowest conditional probability of surgical or endoscopic intervention. Unknown FBs have an intermediate likelihood of intervention. On the other hand, sharp-pointed objects, food bolus, multiple magnets, and disk batteries increase the chances of intervention. Among these, button batteries have the highest probability of intervention after ingestion (OR=3.26). Button batteries pose a significant risk due to their electrical discharge current, causing tissue burns and liquefaction necrosis within 2-3 hours of ingestion [29]. Immediate endoscopic extraction is required for disk batteries [29–31].

Gender and age are the last two variables included in the nomogram. Similarly to previous reports, our cohort primarily consisted of males and preschoolers (75%), aged 2–3 years, [19]. However, gender and age are generally considered potential confounders, and their contribution to the nomogram is relatively modest (5 and 10 points, respectively).

Our study boasts several strengths, including a large population size and a multicenter design involving most pediatric endoscopy units in Italy. These factors enhance the robustness and generalizability of our findings.

To our knowledge, this study is the first attempt to develop a nomogram using a robust statistical approach for predicting the need for invasive intervention in children presenting to the ED with a FBI. Given that decision-making in these cases primarily

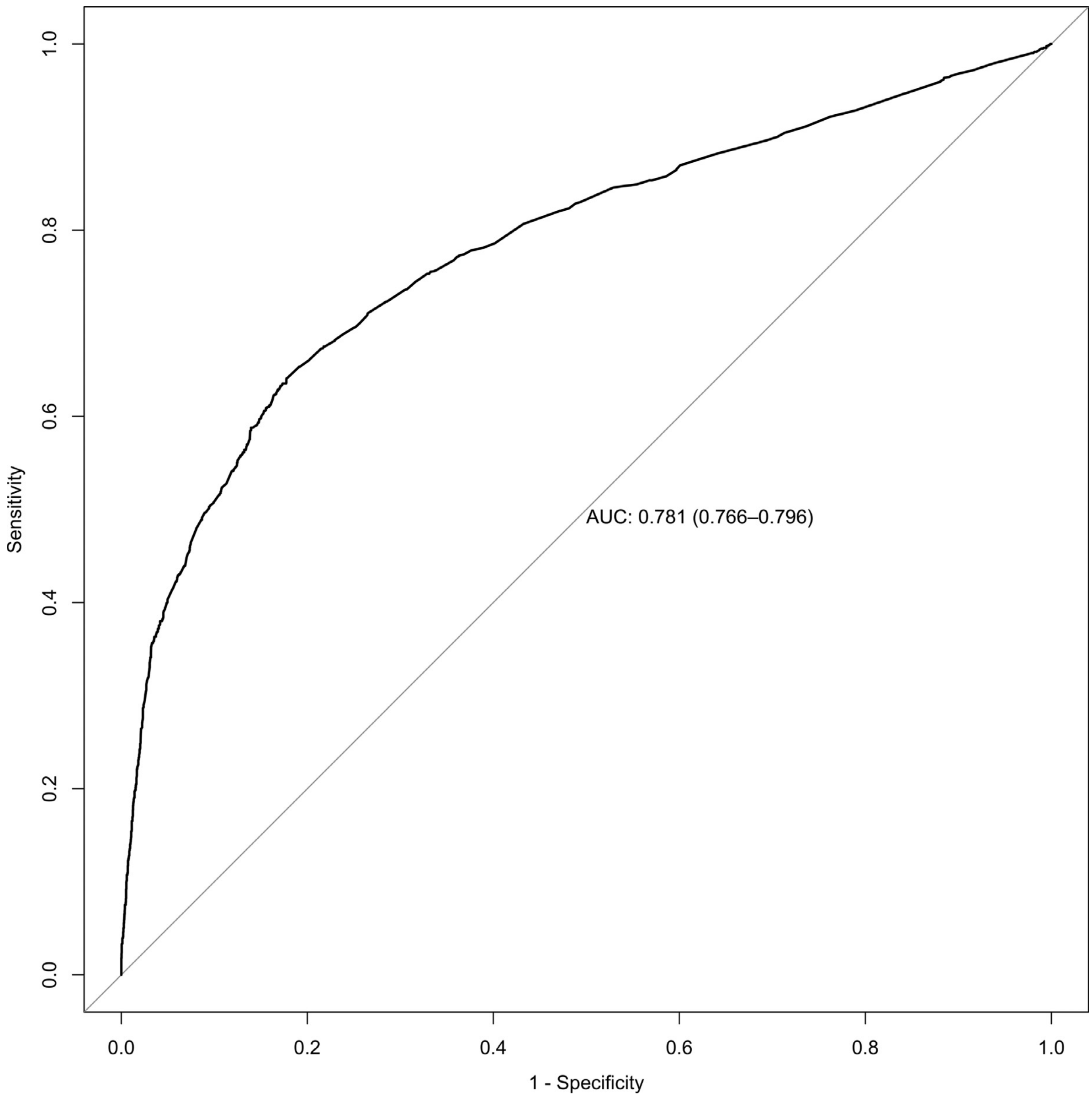

Fig. 3. Predictive accuracy of the multivariable logistic regression model: Receiver Operating Characteristic (ROC) curve plot.

falls on ED physicians rather than just surgeons or endoscopists, it is crucial to disseminate the results of this study to them.

Some limitations should be acknowledged. First, the retrospective nature of the study may introduce biases in the statistical analysis and nomogram development. However, the inclusion of a large sample size and multiple centers help mitigate this risk, and the calibration analysis supports the validity of this model. Nonetheless, prospective validation of the nomogram is necessary to verify its effectiveness in clinical practice.

Second, the nomogram is based on the medical clinical decision made by the ED physician, regarding symptoms and FB location, rather than the outcome of the enrolled children. This approach reflects the real-world decision-making process but introduces a potential limitation.

Standardization of FBI management is undoubtedly needed, considering that data collection spanned from 2015 to 2020, and different hospitals followed guidelines published by ESPGHAN, SIGENP, or NASPGHAN in different years with varying recommendations. However, proposals for endoscopic referral have shown reasonably consistency across guidelines.

To confirm the validity of these findings, the SIGENP Endoscopy Working Group will initiate a new prospective multicenter study, in which all participating hospitals will adhere to the latest SIGENP guidelines published in 2020 [10].

In conclusion, based on admission information, we present the first nomogram as a tool to predicting the likelihood of surgical/endoscopic intervention in children with FBI to the ED. This nomogram can assist pediatricians and general practitioners in making medical decisions regarding FBI in children before resorting to imaging or referring patients to endoscopists and pediatric surgeons. However, it is crucial to emphasize that this nomogram should not replace imaging, which remains a cornerstone of FBI management. The ability to assess the need for an urgent endoscopy could potentially revolutionize the current management of on-call endoscopists, particularly in countries like Italy where their availability may be limited [32]. Risk stratification based on the nomogram may be the most suitable approach to maximize resources and enhance patient care in EDs where access to an on-call endoscopist is unavailable.

Conflict of interest

None.

Author contribution

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Acknowledgement

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.dld.2023.07.017.

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