The Turkish Journal of Pediatrics 2023; 65: 1002-1011
https://doi.org/10.24953/turkjped.2023.338

Original Article

Computed tomography with clinical scoring to differentiate phytobezoar from feces in childhood small bowel obstruction

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ABSTRACT

Background. Identification of phytobezoar in childhood small bowel obstruction (SBO) characterized by small-bowel feces sign (SBFS) is still challenging. The aim of our study was to assess the diagnostic performance of quantitative computed tomography (CT) analysis combined with the Acute General Emergency Surgical Severity-Small Bowel Obstruction (AGESS-SBO) scoring system in determining phytobezoar-related SBO.

Methods. Sixteen phytobezoar-related SBO were categorized as the phytobezoar group and the other 19 SBFS-positive SBO was categorized as the control group. Demographic data, clinical presentation, and laboratory and CT findings were collected and analyzed. Each patient's AGESS-SBO score was determined according to the individual medical record. Multivariate logistic regression analyses were used to identify significant variables associated with phytobezoar-related SBO. Diagnostic performance of key variables was assessed using receiver operating characteristic (ROC) curve analysis.

Results. Compared to the control group, the phytobezoar group showed a significantly shorter debris maximal length (3.0 ± 0.5 cm vs. 3.5 ± 0.7 cm, P<0.05), stronger attenuation (12.6 ± 5.9 HU vs. 8.2 ± 4.0 HU, P <0.05) in CT, and higher AGESS-SBO scores (4.5 [interquartile (IQR): 4–5]) vs. (2 [IQR: 1–4]). With the combination of debris attenuation (with a cut-off of >9.0 HU) and AGESS-SBO score (with a cut-off of >3 points), the positive predictive value (PPV) and negative predictive value (NPV) to diagnose phytobezoar-related SBO were 80% (12/15) and 84% (16/19), respectively.

Conclusions. The diagnostic method of integrating quantitative CT analysis and the AGESS-SBO scoring system can improve the identification accuracy of phytobezoar in SBFS-positive childhood SBO.

Key words: bezoars, feces, intestinal obstruction, differential diagnosis.

The presence of phytobezoar contributes to 6% of unusual etiologies of small bowel obstruction (SBO), and it could cause serious complications, such as bowel bleeding, perforation, and fistula formation.[1] Small-bowel feces sign (SBFS) obtained from morphological assessment of computed tomography (CT) in SBO can imply the existence of phytobezoar, but it is also the common CT manifestation of a series of SBO without phytobezoar which could be treated conservatively.[2,3] Quantitative analysis of CT works effectively in distinguishing phytobezoar from feces in adult SBO[3-6], but whether it is also practically efficient in children's SBO remains unclear.

Recently, the Acute General Emergency Surgical Severity-Small Bowel Obstruction (AGESS-SBO) scoring system was proven effective in categorizing SBO in adults.[7] In this study, by re-evaluating clinical and imaging information of 35 SBFS-positive childhood SBO, we further explored the clinical differences between

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Received 5th May 2023, revised 9th Jul 2023, 2nd Sep 2023, accepted 9th Nov 2023.

This manuscript has been previously published as a preprint on the Research Square Preprint system. https://www.researchsquare.com/article/rs-2354568/v1

phytobezoar and non-phytobezoar related SBFS-positive SBO using quantitative CT combined with the AGESS-SBO scoring system (qCT+ASSS). We tried to provide effective ways to improve diagnostic accuracy and facilitate appropriate clinical decisions in SBFS-positive childhood SBO especially when the presence of phytobezoar should be considered.

Material and Methods

Patient population

The study protocol was approved by the Institutional Ethics Committee of the First Affiliated Hospital of Dali University (number: 20190098). Two hundred fourteen pediatric patients were treated for SBO between July 2009 and June 2016. Sixteen patients without prior abdominal operation were diagnosed with phytobezoar-related SBO (Fig. 1). For the control group, we included 19 SBO with CT findings of SBFS who had not undergone surgical intervention on the abdomen before. Among these 19 children, 17 incomplete obstructions were resolved after conservative treatment and were not hospitalized again in the following 2 months because of SBO; Vitelline duct anomalies were confirmed in the other 2 cases in the subsequent operation, one was omphalomesenteric cord and another was Meckel's diverticulum.

Clinical data

The following clinical data were recorded for each patient: symptoms, signs, laboratory tests, and intraoperative findings.

Radiological examination and analyses

All children underwent an unenhanced CT scan. Scanning was performed by a 16-slice multidetector CT system (Philips Healthcare Brilliance, Netherlands). CT parameters used were slice thickness, 3 mm; beam collimation, 0.5 mm; pitch, 1.5; tube voltage, 120 kV; and maximum tube current, 250 mA. CT images were analyzed on a picture archiving and communications system (PACS) (Digital Imaging and Communications in Medicine [DICOM] 3.0).

All CT images were reevaluated retrospectively in a blind fashion by an experienced radiologist. The following quantitative CT findings were analyzed: (1) obstruction degree; (2) presence of air-fluid levels in the distended bowel; (3) pneumoperitoneum, defined as the presence of free gas in the peritoneal cavity, intestinal clearance, or subphrenic space; (4) intraperitoneal fluid, defined as the presence of liquid in the hepatorenal recess, splenorenal recess, intestinal clearance, or pelvic cavity; (5) size of food debris sign (in cm), measured as the maximal length of the intraluminal mass

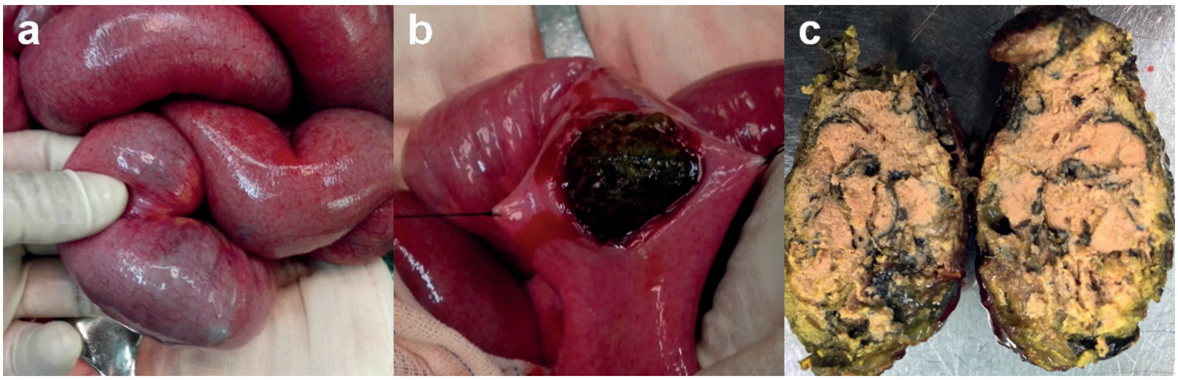

Fig. 1. Intraoperative findings of 6-year-old boy was diagnosed small bowel obstruction leading by phytobezoar. (a). A hard olive-like mass impacted in the lumen of ileum without bowel necrosis and perforation, except to bowel edema, distention, and congestion. (b).The phytobezoar was exposed in the enterotomy. (c). The longitudinal section of phytobezoar.

located at the transitional site of the proximal dilated loop and distal collapsed loop; and (6) debris attenuation (in Hounsfield units [HU]), which was averaged from four measurements for each mass.

AGESS-SBO scoring system

All patients were evaluated according to the AGESS-SBO scoring system.[7] We used on-admission parameters for anatomy and physiology in the current study. The anatomic criteria were scored as 0–5 points. Obstruction degree and perforation of bowel were evaluated by CT imaging.[8] Physiological changes were also scored between 0–5 based on the pathological severity, including systemic inflammatory response syndrome (SIRS), sepsis, severe sepsis, septic shock, and multiple organ dysfunction syndrome determined by international consensus in pediatric patients (Table I).[9] With individual scores from anatomic and physiological parameters, we assigned patients a total score as follows:

AGESS-SBO scores = anatomic scores^2 + *physiological scores*^{2}

Statistical analyses

Categorical data were reported as frequencies and percentages and compared between groups by using the chi-squared test; continuous data was reported as means (± standard deviations) or medians (interquartile range [IQR]) and compared between groups by using the independent *t*-test or non-parametric test. Correlation between CT findings and AGESS-SBO scores was tested by spearman rank correlation. Binary logistic regression was used to assess possible associations of several CT findings and AGESS-SBO scores with phytobezoar-related SBO. Logistic regression was used to calculate odds ratios (ORs) of phytobezoar-related SBO, depending on the presence of certain CT findings and certain AGESS-SBO scores. Receiver operating characteristic (ROC) curves were used to determine the optimal cut-off values for CT parameters and the AGESS-SBO score for differentially diagnosing phytobezoar-related SBO. The diagnostic performance by combining these factors was assessed by calculating the area under the ROC curve (AUC).

Table I. AGESS-SBO scoring system.

Component	Scale score
Anatomic	
Normal	0
Incomplete SBO without the need of operation	1
Completed SBO without strangulation	2
Completed SBO with strangulation	3
Perforation with local peritonitis	4
Perforation with diffuse peritonitis	5
Physiological	
Normal physiology	0
SIRS	1
Sepsis	2
Severe sepsis	3
Septic shock	4
Multiple organ dysfunction syndrome	5

AGESS-SBO: Acute General Emergency Surgical Severity-Small Bowel Obstruction, SBO: small bowel obstruction, SIRS: systemic inflammatory response syndrome

Results

Clinical findings

The group with phytobezoar contained 11 boys and 5 girls, with a mean age of 7.2 ± 3.2 yrs. The control group contained 11 boys and 8 girls, with a mean age of 6.0 ± 3.1 yrs. More phytobezoar patients presented with vomiting (P = 0.001), abdominal distention (P = 0.003), and higher white blood cell counts (P = 0.003). Other symptoms and laboratory tests did not differ significantly between the two groups (Table II).

AGESS-SBO scores

The median of anatomic scores in the phytobezoar group was greater than in the control group (P=0.001). A greater median

Table II. Comparative analysis of clinical and laboratory parameters between phytobezoars and feces groups.

Clinical parameters	Phytobezoars group (n=16)	Feces group (n=19)	p value*
Age	7.2±3.2	6.0±3.1	0.254
Sex			0.508
Male	11 (69%)	11 (58%)	
Female	5 (31%)	8 (42%)	
Clinical symptoms			
Fever (> 37.7 °C)	3 (19%)	2 (11%)	0.489
Vomiting	13 (81%)	5 (26%)	0.001*
Abdominal pain	14 (88%)	12 (63%)	0.181
Constipation	10 (63%)	11 (58%)	0.782
Dehydration	7 (44%)	7 (37%)	0.678
Abdominal distention	13 (81%)	11 (58%)	0.003*
Muscle guarding	4 (25%)	3 (16%)	0.497
Abdominal masses	2 (13%)	1 (5%)	0.446
Laboratory tests			
White blood cells count ($\times 10^9$/l)	11.0±2.9	8.1±2.4	0.003*
Netrophil percentage (%)	62.6±24.2	52.8±18.8	0.189
Blood amylase (IU)	67.9±32.1	52.4±15.2	0.07
Urine amylase (IU)	564.1±229	492.2±134.8	0.257
[K+] (mmol/l)	4.4±0.5	4.2±0.5	0.318
[Na+] (mmol/l)	140.3±5.8	139.5±5.9	0.697

[K^+]: serum potassium concentration, [Na^+]: serum sodium concentration, IU: international unit
Categorical data are indicated as number of patients (percentage, %). Measurement data are indicated by mean± standard deviation. *p value <0.05 statistical significance

Table III. The distribution of patients' AGESS-SBO scores.

Components	Score	Phytobezoars group (n=16)	Feces group (n=19)
Anatomic			
Normal	0	0 (0)	0 (0)
Partial SBO	1	6 (38%)	14 (74%)
Complete SBO without rebound tenderness	2	8 (50%)	5 (26%)
Complete SBO with rebound tenderness	3	2 (12%)	0 (0)
Complete SBO with perforation or local muscle guarding	4	0 (0)	0 (0)
Diffuse muscle guarding	5	0 (0)	0 (0)
Physiological		5 (31%)	
Normal	0	11 (69%)	17 (89%)
SIRS	1	0 (0)	2 (11%)
Sepsis	2	0 (0)	0 (0)
Serve Sepsis	3	0 (0)	0 (0)
Septic shock	4	0 (0)	0 (0)
MODS	5	4.8±1.9	0 (0)
AGESS-SBO score	50	4.8±1.9	2.3±1.5

AGESS-SBO: Acute General Emergency Surgical Severity-Small Bowel Obstruction, MODS: multiple organ dysfunction syndrome, SBO: small bowel obstruction, SIRS: systemic inflammatory response syndrome.
Categorical data are indicated as number of patients (percentage, %). Measurement data are indicated by mean± standard deviation.
*p value <0.05 statistical significance

Table IV. Comparative analysis of CT variables between phytobezoars and feces groups.

CT variable	Phytobezoars group (n=16)	Feces group (n=19)	P Value*
Obstruction levels			0.031*
Incomplete	6 (38%)	14 (74%)	
Complete	10 (62%)	5 (26%)	
Air-fluid level	16 (100%)	18 (94%)	0.377
Pneumoperitoneum	0 (0)	0 (0)	
Intraperitoneal fluid	9 (56%)	7 (37%)	0.251
Food debris description			
Size			
Long axis (cm)	3.0±0.5	3.5±0.7	<0.001*
Short axis (cm)	2.5±0.5	2.6±0.6	0.775
Attenuation			
Mean value (HU)	12.6±5.9	8.2±4.0	0.014*
Minimal value (HU)	2.4	2.1	
Maximal value (HU)	28	15.9	

Categorical data are indicated as number of patients (percentage, %). Measurement data are indicated by mean± standard deviation. *p value <0.05 statistical significance. CT: computed tomography, HU: Hounsfield unit.

AGESS-SBO score was seen in the phytobezoar group (P<0.001). Half of the 16 children (50%) in the phytobezoar group scored more than 4 points based on the AGESS-SBO scoring system, whereas 18 of the 19 children (95%) from the control group scored fewer than 4 points (Table III).

CT findings

The primary CT finding in both groups was air-fluid levels in a dilated bowel loop, with children in the phytobezoar group showing a higher frequency of complete obstruction (Fig. 2). Intraperitoneal fluid did not differ significantly between the two groups (P=0.377). Food debris signs were detected in all children in the control group. The maximal length was significantly shorter in children with phytobezoars (P=0.01). Attenuation was significantly higher in children with phytobezoars (P =0.014, Table IV).

Correlation between CT findings and AGESS-SBO scores

Significant variables of CT findings, including obstruction levels, attenuation and maximal length were analyzed with AGESS-SBO scores in terms of correlations. There was a positive correlation between attenuation and AGESS-SBO scores (P=0.001). There were no correlation between the rest of the CT findings (obstruction levels and maximal length) and AGESS-SBO scores (P>0.05, Table V).

Diagnostic performance analysis AGESS-SBO scores

Binary logistic regression identified the following factors as evidence of a significant association with phytobezoar-related SBO: higher AGESS-SBO scores, more serious obstruction, shorter maximal length of debris, and stronger debris attenuation (P <0.05, Table VI). The following factors did not show a significant association with phytobezoar-related SBO: air-fluid level and intraperitoneal

Table V. Correlation between CT findings and AGESS-SBO scores.

CT findings	AGESS-SBO scores	
	Spearman' rank	P
obstruction levels	-0.215	0.115
Long axis (cm)	-0.203	0.242
Attenuation	0.522	0.001*

AGESS-SBO: Acute General Emergency Surgical Severity-Small Bowel Obstruction, CT: computed tomography.

Table VI. Results of multivariate analysis by means of logistic regression.

Effects	OR	95% CI	P Value*
AGESS-SBO score	2.847	1.377,5.888	0.005*
Obstruction level	0.214	0.051, 0.902	0.036*
Air-fluid level	0.360	0.033, 3.805	0.393
Intraperitoneal fluid	0.454	0.117, 1.764	0.254
Debris long axis (cm)	0.190	0.046, 0.781	0.021*
Debris short axis (cm)	0.831	0.244, 2.830	0.767
Debris attenuation (HU)	1.220	1.024, 1.453	0.026*

*p value <0.05 statistical significance. AGESS-SBO: Acute General Emergency Surgical Severity-Small Bowel Obstruction, CI: confidence interval, HU: Hounsfield unit, OR: odds ratio.

Table VII. The area under the curve of correlated effects of phytobezoars-related SBO.

Variable	AUC	95% CI	P Value
AGESS-SBO scores	0.850	0.720, 0.980	<0.001
Obstruction level	0.319	0.137, 0.501	0.049
Debris long axis (cm)	0.266	0.101, 0.432	0.019
Debris attenuation (HU)	0.755	0.590, 0.920	0.010
CT findings	0.819	0.677, 0.961	0.001
Debris attenuation+AGESS-SBO scores	0.896	0.787, 1.000	<0.001
CT findings+AGESS-SBO scores	0.918	0.826, 1.000	<0.001

AGESS-SBO: Acute General Emergency Surgical Severity-Small Bowel Obstruction, CI: confidence interval, CT: computed tomography, HU: Hounsfield unit, OR: odds ratio.

fluid (P >0.05). Based on AUC analysis, phytobezoar-related SBO was weakly predicted by obstruction level and maximal length of food debris (AUC <0.5) and strongly predicted by AGESS-SBO score and food debris attenuation (AUC >0.5). The AUC of certain CT findings (including obstruction level, maximal length of debris, and debris attenuation), the combination of debris attenuation and AGESS-SBO score, as well as the combination of CT findings and AGESS-SBO score were greater than 0.5 (Table VII).

Using a food debris attenuation cut-off of >9.0 HU, we calculated a sensitivity of 81% (13/16), specificity of 68% (13/19), positive predictive value (PPV) of 68% (13/19), and negative predictive value (NPV) of 65% (13/20). The PPV and NPV, using the combination of debris attenuation (with cut-off of >9.0 HU) and AGESS-SBO score (with cut-off of >3points), were 80% (12/15) and 84% (16/19), respectively.

Discussion

Operative intervention would be considered for SBO caused by phytobezoar, which is a trapped mass of undigested food leading to mechanical intestinal obstruction with higher risk of bowel strangulation.[1] On the contrary, a non-operative approach could be effective for treating a series of SBFS-positive SBO without phytobezoar which develops secondary to increased water absorption and delayed transit.[10] Inappropriate or delayed diagnosis of phytobezoar-related SBO may result in bowel bleeding, perforation, or fistula formation, which will threat patients' life, bring about longer hospital stays and increased cost. Therefore, a more effective diagnostic methodology needs to be established to differentiate phytobezoar effectively from feces in childhood SBO. In the present study, we developed a combined diagnostic approach based on qCT+ASSS, which can improve the diagnostic performance to identify phytobezoar-

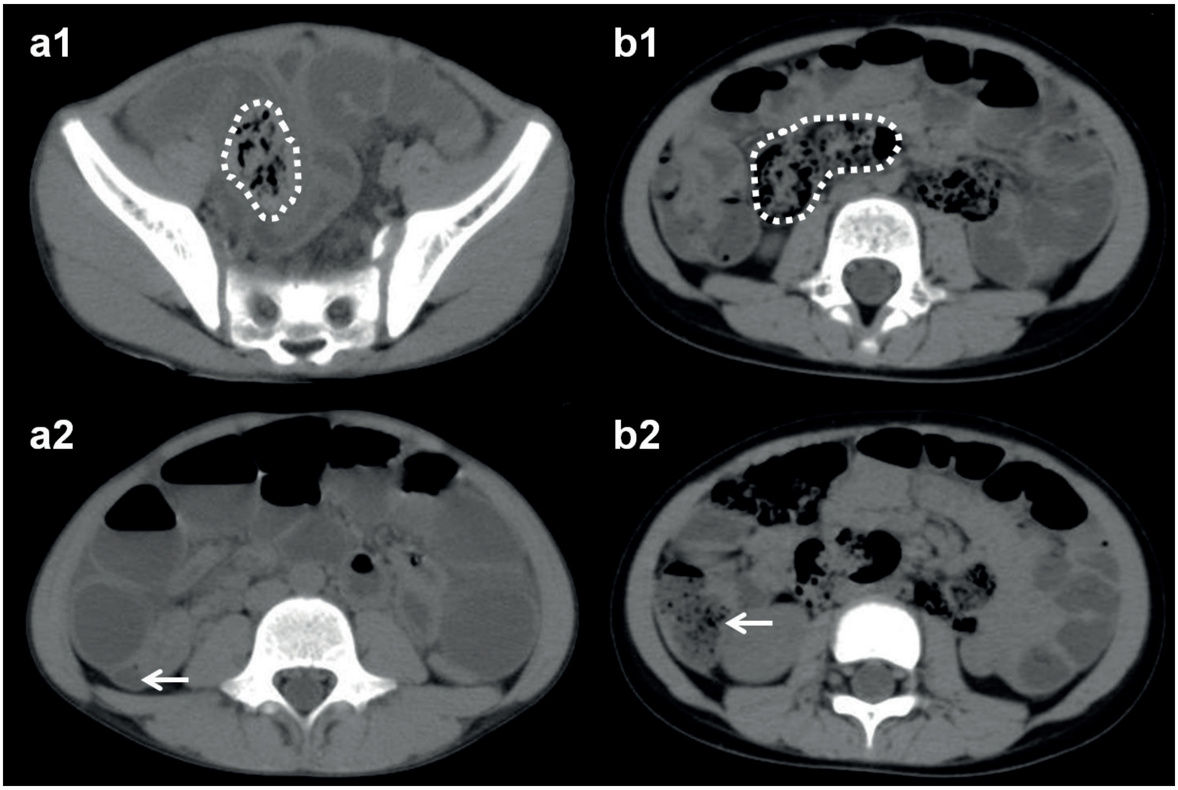

Fig. 2. The differences of unenhanced CT features between phytobezoar and feces in two children with small bowel obstruction. **a1, a2:** A 11-year-old boy was diagnosed with phytobezoar-related obstruction. The size of the intraluminal mass measured about 3.2 × 2.8 cm, and mean attenuation was 11.4 HU (a1, dotted outline). Only minimal liquid was seen in the ascending colon (a2, arrow). **b1, b2:** A 3-year-old girl was diagnosed with incomplete obstruction. The size of the food debris was about 4.8 × 2.6 cm, and mean attenuation was 2.1 HU (b1, dotted outline). A moderate amount of gas and stool was observed in the ascending colon (b2, arrow).

caused SBO, one kind of SBFS-positive SBO that needs to be removed by surgery.

The advent of CT allows surgeons to find visible details, assisting clinical decision making in the management of phytobezoar-related SBO.[3,4,6,11] Early image-based differentiation between phytobezoar and feces was based on morphological characteristics, such as SBFS[5], the presence of an encapsulating wall in the case of phytobezoar[3], or more tubular shape in the case of feces.[4] However, the diagnostic performance of morphological findings from CT was greatly affected by variability between observers. Study of quantitative CT, including measurement of food debris length and mean attenuation may improve diagnostic performance in differentiating phytobezoar from feces.[6] Our study showed that further analysis in children with SBFS-positive SBO is essential for differentiating phytobezoar from feces. Quantitative CT analysis turned out to be helpful in finding radiological differences of childhood phytobezoar and feces. Children with quantitative CT features such as shorter debris maximal length and stronger attenuation are more likely to have phytobezoar-related SBO. Stronger debris attenuation accompanied by presentation of complete bowel obstruction indicates irreversible obstruction occurring in phytobezoar-related SBO.

Although quantitative CT resolution has helped surgeons discriminate phytobezoar from feces in SBO, differential diagnosis of SBO in children is still challenging. On the one hand, single quantitative image-based analysis is not efficient. Our study shows that only debris attenuation has predictive value and, meanwhile, with the cut-off value of the debris attenuation (>9 HU), the lower PPV (68%, 13/19) and NPV (65%, 13/20) indicate a potentially unrecognized phytobezoar and missed diagnosis. On the other hand, acute SBO is progressive, and variates determined by quantitative CT justly reflect anatomic changes of the SBO, which is one aspect of disease development. Clinical features, patients' pathophysiological responses to SBO caused by different etiological factors, are also critical for judgment. In fact, increased studies in adults have elucidated the preferable performance of a treatment algorithm for SBO based on patients' CT findings and clinical features.[8,12,13] However, these effective clinical guidelines validated in adult studies cannot be applied to childhood SBO because of different causes and various clinical features in two different patient populations. A diagnostic method integrating quantitative CT analysis and clinical features for children with SBO is therefore greatly needed. In the present study, frequent vomiting, progressive abdominal distension, as well as increased white blood cells were more commonly observed in the phytobezoar group. It shows that clinical features could be practical for identify phytobezoar-related SBO in SBFS-positive SBO. In addition, with the advantage of consecutive evaluation, clinical features can reflect the progression of childhood SBO in a timely way. Therefore, the establishment of a more effective diagnostic method of differentiating phytobezoar from feces in SBO should incorporate existing quantitative CT findings in patients' clinical features.

The AGESS-SBO scoring system, a systematic tool consisting of anatomic, physiological, and comorbidity parameters[7], is a relatively practical and comprehensive system that integrates CT findings and clinical features in the management of SBO. Based on quantitative CT findings, we developed a combined method that integrates quantitative CT analysis and the AGESS-SBO scoring system to differentiate phytobezoar from feces in childhood SBO. The criteria for evaluating anatomic parameters in the AGESS-SBO system relied on findings from enhanced CT performed with the use of contrast materials and higher radiation dose to recognize potential bowel ischemia. We noticed that few children with phytobezoar had undergone bowel strangulation in the early stage of hospitalization. Therefore, the prioritized purpose of CT in clinical decision making concerning phytobezoar-related SBO is to obtain imaging features of debris rather than to discover potential bowel ischemia. In fact, the signs obtained from physical examination are workable to identify potential bowel strangulation. Moreover, radiation damage to children, including the risk of radiation-induced cancer should be considered when enhanced CT is applied.[14,15] The comorbidity index, which assessed the relationship between perioperative complications and age-related diseases such as diabetes and hypertension[16], was limited by the sample size in this study. Appropriate modifications of the AGESS-SBO scoring system could be more suitable for management of childhood SBFS-positive SBO.

Assessment of results showed that the higher AGESS-SBO scores presented in the phytobezoar group were correlated with higher degree of obstruction and development of SIRS. In fact, phytobezoar-related SBO in children was more likely associated with dramatic anatomic and physiological changes.[17] However, SBFS-positive CT findings can appear in patients without SBO.[18,19] Increased PPV (80% (12/15)) and NPV (84% (16/19)) by the use of qCT+ASSS we developed in the present study could potentially decrease missed diagnosis or misdiagnosis. Differentiation based on high-performance diagnostic methods is efficient and can further guide appropriate clinical decision making in the management of phytobezoar-related SBO.

There are some limitations in our study. First, our diagnostic assessment is limited by its retrospective design and small sample size. In addition, patients selected in the control group had no abdominal operation history, which were to be comparable with the history of affected children with phytobezoar-related SBO. It might not reflect the overall situation of SBFS-positive SBO. Ultimately, more SBO-related parameters could be considered in future studies to improve the differential diagnosis of pediatric SBO further.

The present study developed an effective diagnostic method, the combination of the AGESS-SBO scoring system and quantitative CT analysis, to identify phytobezoar-related SBO in childhood SBFS-positive SBO. This method is effective and practical to identify the unrecognized phytobezoar, make appropriate clinical decisions for phytobezoar-related SBO. Thus, we suggest this new method be applied in the clinical management of childhood phytobezoar-related SBO.

Acknowledgements

We thank the Department of Medical Imaging at the First Affiliated Hospital of Dali University for their careful management and evaluation of images.

Ethical approval

The study was approved by the Institutional Ethics Committee of the First Affiliated Hospital of Dali University (number: 20190098). Research work was performed in accordance with the Declaration of Helsinki.

Author contribution

The authors confirm contribution to the paper as follows: analysis, interpretation and draft manuscript preparation: NW, data collection: XL, WS, cases scoring: SZ, revised manuscript: XW. All authors reviewed and approved the final version of the manuscript.

Source of funding

The authors declare the study received no funding.

Conflict of interest

The authors declare that there is no conflict of interest.

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