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Predicting early recurrence after hydrostatic reduction of pediatric intussusception: A nomogram and a simplified clinical score

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ABSTRACT

Objective: Early recurrence after successful hydrostatic reduction of intussusception occurs in 5–15% of children and often requires repeat intervention, yet reliable predictors remain incompletely defined. To identify clinical and sonographic predictors of early recurrence (within 48 h) after ultrasound-guided hydrostatic reduction of ileocolic intussusception, and to develop a weighted nomogram and a simplified bedside score for risk stratification.

Methods: This retrospective study included 677 children who underwent successful ultrasound-guided hydrostatic reduction between January 2020 and December 2025. Early recurrence occurred in 66 patients (9.7%). Predictors were identified by LASSO regression and multivariable logistic analysis. A nomogram was constructed, and a simplified scoring system was derived for rapid bedside use. Recurrence timing was analyzed using Kaplan-Meier curves and Spearman's correlation.

Results: Five independent predictors were identified: transverse colon location (OR 4.647), previous intussusception history (OR 2.831), target sign diameter > 35 mm (OR 1.075 per mm), peritoneal effusion (OR 2.476), and sonographic features of enteritis (OR 2.347). The nomogram showed good discrimination (AUC 0.805). The simplified score (0–5), assigning 1 point to each predictor, also demonstrated acceptable discrimination (AUC 0.795), with a cutoff of 3 points optimally balancing sensitivity (62.1%) and specificity (84.3%). Median recurrence time was 23 h; recurrences were evenly distributed across the 48-h window, and the five predictors did not influence the exact timing of recurrence.

Conclusion: A weighted nomogram and a simple bedside score based on five clinical and sonographic features accurately predict early recurrence after hydrostatic reduction of ileocolic intussusception. The tools enable individualized risk assessment and support risk-stratified observation strategies.

1. Introduction

Acute abdominal emergencies in the pediatric population frequently involve intussusception, a condition characterized by the invagination of a proximal bowel segment into the lumen of the adjoining distal loop [1]. Among the various anatomical subtypes, ileocolic intussusception predominates and represents the most common indication for non-surgical reduction in young children [2]. Epidemiologically, the disorder exhibits a clear age predilection, with the highest incidence observed between 4 and 10 months of age, followed by a rapid decrease after the second year of life [3]. The clinical spectrum ranges from classic episodic abdominal pain, vomiting, and passage of red currant jelly stool to nonspecific manifestations such as lethargy or irritability, which may delay diagnosis and increase the risk of complications [4].

Currently, ultrasonography has emerged as the primary imaging modality for the diagnosis of intussusception in children. This technique is non-invasive, free of ionizing radiation, and clearly demonstrates characteristic findings of the intussuscepted bowel, such as the "target sign" on transverse sections, with diagnostic accuracy exceeding 98% [5]. Leveraging its high resolution and real-time dynamic imaging capabilities, ultrasound can accurately assess the location of the intussusception, the diameter of the intussusceptum, the degree of bowel wall edema, the presence of peritoneal fluid, and blood flow within the bowel wall, offering key information for clinical decision-making. Building on its excellent diagnostic performance, ultrasound-guided hydrostatic reduction has also gained widespread clinical application in recent years. This technique employs warm saline instilled under real-

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time sonographic monitoring to achieve reduction, completely eliminating the ionizing radiation associated with traditional fluoroscopic guidance while enabling dynamic visualization of the entire reduction process and immediate assessment of outcomes [6]. Consequently, its use has expanded across a growing number of institutions.

Although the initial success rates of hydrostatic reduction are favorable, a subset of children experience recurrence shortly after the procedure. Published data indicate that 5% to 15% of patients develop recurrent intussusception, with a substantial fraction occurring within the first 48 h post-reduction [7-9]. Such early recurrences often necessitate repeat enema attempts or surgical intervention, imposing additional physical and emotional stress on the child and family, prolonging hospital stay, and increasing healthcare costs [6]. From a practical standpoint, the ability to forecast which children are at heightened risk for early recurrence would greatly assist emergency physicians and pediatric surgeons in making evidence-based decisions regarding post-reduction observation, admission, or discharge. While prior investigations have identified various factors associated with recurrent intussusception, most have not differentiated between early and late events, and few have systematically evaluated pre-reduction sonographic parameters, such as the maximal diameter of the intussusceptum, its colonic location, the presence of peritoneal fluid, bowel wall thickness, or coexisting intraluminal lesions, as potential predictors of early recurrence. Addressing this gap, the current study was undertaken to delineate clinical and ultrasonographic determinants of recurrence occurring within 48 h after successful ultrasound-guided hydrostatic reduction of ileocolic intussusception in children, and to construct a clinically applicable predictive tool that can enhance post-reduction management strategies.

2. Materials and methods

2.1. Study design and setting

This retrospective cohort study was conducted at the First People's Hospital of Lianyungang, a tertiary pediatric referral center in eastern China. The study protocol was approved by the Ethics Committee of the First People's Hospital of Lianyungang (approval No. KY-20250813002-02) and conducted in accordance with the Declaration of Helsinki. Informed consent was waived by the Ethics Committee due to the retrospective nature of the study.

2.2. Study population

We retrospectively analyzed consecutive pediatric patients diagnosed with acute ileocolic intussusception who presented to our emergency department between January 2020 and December 2025. Ileocolic intussusception was confirmed by clinical presentation, physical examination, and ultrasonography demonstrating the characteristic “target sign” or “pseudokidney sign,” after exclusion of other etiologies such as secondary intussusception caused by pathological lead points (e.g., Meckel diverticulum, intestinal polyp, or lymphoma).

2.3. Inclusion and exclusion criteria

Inclusion criteria were: (1) age < 18 years; (2) acute ileocolic intussusception confirmed by ultrasound; (3) successful ultrasound-guided hydrostatic reduction performed within 48 h of symptom onset; (4) complete clinical and ultrasonographic data available; and (5) standardized 48-h post-reduction observation completed with documented outcome.

Exclusion criteria were: (1) pneumatic reduction performed as the initial or salvage procedure; (2) failed hydrostatic reduction requiring surgical intervention; (3) secondary intussusception with identified pathological lead point requiring surgery; (4) require surgery performed >48 h after symptom onset; (5) recurrence occurring >48 h after successful reduction; (6) incomplete medical records or loss to follow-up during the observation period.

2.4. Definition of early recurrence

The definition of early recurrence following successful hydrostatic reduction for intussusception has varied considerably across studies, with reported time thresholds ranging from 12 to 72 h in earlier reports [8,10,11]. In recent years, however, a 48-h cutoff has been increasingly adopted in the literature. Accordingly, the present study defined early recurrence as recurrent intussusception confirmed by ultrasound within 48 h after successful hydrostatic reduction, based on the presence of a concentric circle sign with mixed echogenicity. This definition was chosen for several reasons: (1) it reflects the current prevailing consensus in the field; (2) previous studies have shown that 92.1% of recurrences occur within this timeframe; [12]. and (3) it aligns with our institutional protocol, which mandates a 48-h observation period following reduction. The time to recurrence was calculated as the interval from successful reduction to ultrasound-confirmed recurrence, recorded in hours.

2.5. Ultrasound-guided hydrostatic reduction protocol

All reductions were performed by pediatric radiologists with >5 years of experience in interventional ultrasound according to standardized institutional protocols. Under real-time sonographic monitoring, warm normal saline (37 °C) was instilled via a Foley catheter positioned in the rectum with the balloon inflated to occlude the anal canal. Saline was infused by gravity with the suspension bag maintained at 80–120 cm above the patient's buttocks, with intermittent manual abdominal compression applied to facilitate reduction. Successful reduction was confirmed sonographically by visualization of fluid passing through the ileocecal valve into the terminal ileum, accompanied by resolution of the intussuscepted mass. The number of reduction attempts was recorded in the procedural report for each patient, with an attempt defined as a discrete session of hydrostatic infusion. If initial reduction was incomplete, subsequent attempts were performed at 30-min to 1-h intervals, with the total number of attempts not exceeding three in accordance with clinical guideline [13].

2.6. Post-reduction observation and data collection

Following successful reduction, all patients were admitted for standardized 48-h inpatient observation. Vital signs and abdominal examinations were performed every 4 h during the first 24 h and every 8 h during the subsequent 24 h. Repeat abdominal ultrasound was performed immediately upon any clinical suspicion of recurrence (recurrent abdominal pain, vomiting, or bloody stool). Patients without recurrence were discharged after 48 h; those with recurrence were managed according to institutional protocols (repeat hydrostatic reduction or surgical intervention). Since all patients remained hospitalized for the entire observation period and recurrence was confirmed by ultrasound before discharge, there was no loss to follow-up or possibility of patients seeking care at other hospitals during this window.

Data were extracted retrospectively from electronic medical records and the institutional radiology information system using standardized case report forms. Clinical variables included: age, sex, season of onset, duration of abdominal pain or crying (hours), presence of vomiting, bloody stool, and history of previous intussusception episodes (>48 h prior to the current admission). Ultrasonographic parameters were obtained from prospectively recorded ultrasound reports and archived images, including: maximal diameter of the intussusceptum (mm), anatomical location of the intussusception (ascending colon, transverse colon), presence and quantity of peritoneal effusion, intestinal wall thickness (mm), presence of enlarged mesenteric lymph nodes. Additionally, peritoneal fluid within the intussusception defined as an

anechoic crescentic area visualized between the serosal layers of the enfolded intussusceptum on axial ultrasound views, was recorded separately, as described by del-Pozo [14]. The measurement of bowel wall thickness was obtained at the unaffected terminal ileum, specifically at a site 2–5 cm proximal to the intussusception mass, with the ultrasound beam oriented perpendicular to the bowel wall [15]. This anatomical site was selected to avoid confounding factors such as edema within the intussusceptum and involvement of the ileocecal valve, both of which are commonly affected during intussusception. Measurements were taken on longitudinal ultrasound sections. A wall thickness of 3 mm or more at this location was regarded as abnormal and indicative of possible concomitant gastroenteritis [16]. A short-axis diameter of ≥8 mm was adopted as the cutoff for defining enlarged mesenteric lymph nodes, in accordance with previous study [17]. All ultrasound examinations were originally performed and interpreted by board-certified pediatric radiologists using standardized scanning protocols and reporting templates; measurements were obtained from the recorded reports, with verification from archived images when report data were incomplete. In cases where discrepancies existed between the initial report and the archived images (less than 5% of cases), a consensus was reached through discussion between two senior pediatric radiologists.

2.7. Sample size calculation

Sample size was calculated based on the Events Per Variable (EPV) principle for multivariable logistic regression analysis [18]. Assuming an early recurrence rate of 5–15%, [7,12], and planning to include 5 independent predictors in the final model, a minimum of 80 recurrence events was required (EPV = 10). Thus, the target sample size was at a range of 334–1000 patients.*Statistical analysis*Statistical analyses were conducted using R software (version 4.3.1). All tests were two-tailed, and $P < 0.05$ was considered statistically significant. The Shapiro-Wilk test was used to assess the normality of continuous variables. Normally distributed data were presented as mean ± standard deviation, and comparisons between two groups were performed using Student's *t*-test. Non-normally distributed data were expressed as median with interquartile range (25th–75th percentile), and differences were evaluated using the Mann-Whitney *U* test. Categorical variables were summarized as frequencies and percentages, and group comparisons were made using the χ^2 test or Fisher's exact test.

Univariate logistic regression was performed to identify potential predictors of early recurrence. It was conducted to estimate odds ratios (OR) and 95% confidence interval (CI) for potential predictors of early recurrence. Variables with $P < 0.10$ in univariate analysis were entered into multivariable logistic regression using backward stepwise selection to identify independent predictors. Least Absolute Shrinkage and Selection Operator (LASSO) regression with 10-fold cross-validation was performed to validate variable selection and prevent overfitting.

A nomogram predicting early recurrence probability was developed based on multivariable logistic regression coefficients. Model discrimination was assessed using receiver operating characteristic (ROC) curve analysis, with calculation of the area under the curve (AUC) and 95% CI. Internal validation was performed using 1000 bootstrap resamples to calculate the optimism-corrected C-index. Calibration was evaluated using calibration plots comparing predicted versus observed probabilities. Clinical utility was assessed using decision curve analysis (DCA) to quantify net benefit across a range of threshold probabilities.

Time-to-recurrence analysis was performed to identify factors influencing the timing of early recurrence. Kaplan-Meier curves were constructed to visualize the distribution of recurrence-free survival during the 48-h observation period, with time to recurrence (in hours) as the outcome variable. The log-rank test was used to compare survival distributions across categorical variables. For continuous variables, the relationship with time to recurrence was evaluated using Spearman's rank correlation coefficient. Univariate Cox proportional hazards regression was performed to estimate hazard ratios (HR) and 95% CI for potential predictors of earlier recurrence. Variables showing association with time to recurrence ($P < 0.10$) in univariate analysis were entered into multivariable Cox proportional hazards regression using backward stepwise selection to identify independent predictors of recurrence timing.

3. Results

3.1. Baseline analysis of general data

A total of 824 pediatric patients with acute intussusception were initially screened between January 2020 and December 2025. Among them, 65 were excluded prior to reduction due to the following reasons: direct surgical intervention without enema attempt ($n = 17$), primary pneumatic reduction ($n = 19$), or secondary intussusception secondary to pathological lead points such as Meckel's diverticulum or intestinal polyps ($n = 29$). The remaining 759 patients underwent ultrasound-guided hydrostatic reduction. Of these, an additional 82 patients were excluded due to failed hydrostatic reduction requiring surgery ($n = 39$), incomplete medical records ($n = 30$), or missing key ultrasonographic images ($n = 13$). Ultimately, 677 patients with successful hydrostatic reduction and complete 48-h follow-up data were included in the final analysis. Among them, 611 patients (90.3%) experienced no recurrence during the observation period and were classified into the non-early recurrence group, while 66 patients (9.7%) developed early recurrence within 48 h post-reduction and were assigned to the early recurrence group (Fig. 1). No significant differences were found between the early recurrence group and non-recurrence groups in age, gender, bloody stool, vomiting, number of reduction or season of onset, whereas differences in duration of abdominal pain and previous history of intussusception were statistically significant. When comparing the ultrasonography features between the two groups, the early recurrence group showed a higher proportion of peritoneal effusion, greater intestinal wall thickness. Additionally, the proportion of cases with the intussusception located in the transverse colon, larger concentric-circle diameter, and those complicated by intraluminal masses was higher in the early recurrence group. However, the presence of enlarged mesenteric lymph nodes did not differ significantly between the groups. A detailed comparison of baseline demographic and clinical characteristics between the two groups is presented in Table 1.

3.2. Identification of sample size

In practice, 824 consecutive patients were screened between January 2020 and December 2025, of whom 677 met the inclusion

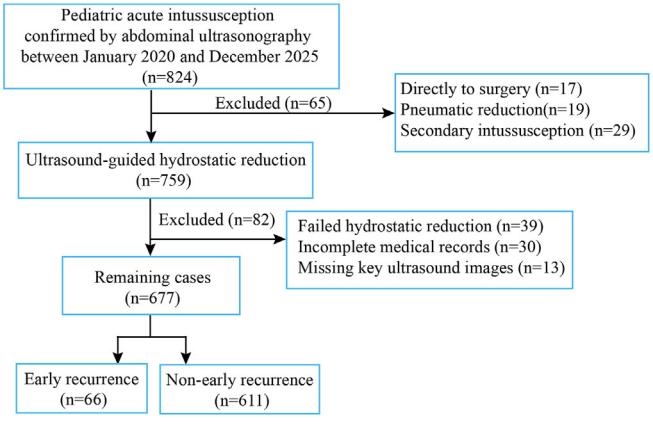

Fig. 1. Flow diagram of patient selection.

Table 1
Baseline comparison of non-early recurrence group and early recurrence group.

Characteristics	Non-early recurrence Group ($n = 611$)	Early recurrence Group ($n = 66$)	*P* value
Age (month),median(IQR)	16 (10, 25)	19 (14, 29)	0.033
Gender,n			
MMMMale	344	44	
Female	267	22	
Bloody stool,n			0.837
Absent	353	39	
Present	258	27	
Vomiting,n			0.125
Absent	396	49	
Present	215	17	
Duration of pain (hour), median (IQR)	17 (11, 29)	25 (17, 32)	<0.001
Season of onset,n			0.924
Spring	178	20	
Summer	132	16	
Autumn	152	16	
Winter	149	14	
Intussusception location,n			<0.001
Ascending colon	455	24	
Transverse colon	156	42	
Enlarged mesenteric lymph node,n			0.365
Absent	316	38	
Present	295	28	
Previous history of intussusception,n			0.003
Absent	64	15	
Present	547	51	
Target sign diameter (millimeter), median (IQR)	35 (30, 42)	40 (35, 45)	<0.001
Peritoneal effusion,n			0.004
Absent	404	32	
Present	207	34	
Features of enteritis,n			<0.001
Absent	176	36	
Present	435	30	
Number of reduction,n			0.879
1	548	58	
2	45	6	
3	17	3	

CI: Confidence interval.

criteria and were enrolled, meeting the minimum required sample size of 467 cases. The actual recurrence rate was 9.7%, yielding 66 recurrence events and an EPV ratio of 13.2, which exceeded the recommended threshold of 10 and confirmed adequate statistical power for the multivariable analysis [19].

3.3. Characteristics of early recurrence timing

Among the 66 patients who experienced early recurrence within 48 h after successful hydrostatic reduction, the median time to recurrence was 23 h (IQR: 15–33 h). The distribution of recurrence times over the 48-h observation period did not deviate significantly from a relatively even distribution, indicating that early recurrences occurred relatively evenly across all 6-h intervals. However, a modest peak was observed in the 18–24 h interval (19.7%) (Fig. 2A). These findings indicate that early recurrence is distributed across the entire 48-h observation window, with a discernible peak in the 18–24 h interval.

For categorical variables (sex, bloody stool, vomiting, season of onset, intussusception location, enlarged mesenteric lymph nodes, previous history of intussusception, peritoneal effusion, features of enteritis, and number of reduction attempts), Kaplan–Meier curves were constructed and compared using the log-rank test. None of these factors showed a significant association with recurrence time (all log-rank $P > 0.05$) (Fig. 2B–K);For continuous variables, Spearman's rank correlation analysis revealed that age ($R = 0.114$, $P = 0.360$) and target sign diameter ($R = 0.048$, $P = 0.700$) were not significantly correlated with time to recurrence. Duration of abdominal pain showed a weak positive correlation that reached statistical significance ($R = 0.362$, $P = 0.003$); however, the magnitude of the correlation was modest and its clinical relevance remains uncertain (Fig. 2L–N).

3.4. Univariate and multivariate analysis

Univariate logistic regression identified several factors associated with early recurrence, including transverse colon location, previous intussusception history, larger target sign diameter, peritoneal effusion, and features of enteritis (all $P < 0.01$). Gender, bloody stool, vomiting, season, enlarged lymph nodes, and number of reduction attempts were not significant.

Multivariate analysis confirmed all five factors as independent predictors of early recurrence: age(OR: 0.955, $P = 0.002$),symptom duration (OR: 1.032, $P = 0.013$), transverse colon location (OR: 4.647, $P < 0.001$), previous history (OR: 2.831, $P = 0.005$), target sign diameter (OR: 1.075, $P < 0.001$), peritoneal effusion (OR: 2.476, $P = 0.002$), and features of enteritis (OR: 2.347, $P = 0.003$) (Table 2).

3.5. Construction of the Nomogram model and validation

To identify the most relevant predictors while avoiding overfitting, we performed Lasso regression with 10-fold cross-validation Fig. 3A displays the cross-validated binomial deviance as a function of log(λ). The left vertical dashed line indicates the λ value with the minimum deviance, and the right vertical dashed line indicates the largest λ within one standard error of the minimum. The numbers at the top of Fig. 1A show the count of non-zero coefficients at each λ: starting with 13 predictors at low λ, the model progressively shrank variables, retaining 5 non-zero coefficients at lambda.1se Fig. 3B illustrates the coefficient paths for all 13 candidate variables across the same λ range. As the penalty increased, coefficients of less important variables (e.g., bloody stool, vomiting) rapidly shrank to zero, indicating their limited contribution. In contrast, variables with stronger associations (e.g., intussusception location, previous history of intussusception) maintained non-zero coefficients well into the higher penalty region. A nomogram was developed from the independent predictors identified by multivariable and LASSO regression, assigning weighted scores that translate directly into individualized recurrence probabilities (Fig. 3C). Internal validation using 1000 bootstrap resamples yielded a C-index of 0.805. The AUC of the ROC curve was 0.805 (95% CI: 0.750–0.861), indicating good discriminative ability (Fig. 3D). The calibration plot showed close agreement between predicted and observed probabilities of early recurrence (Fig. 3E). Decision curve analysis demonstrated a positive net benefit across a wide range of threshold probabilities (Fig. 3F).

3.6. Simplified risk stratification tool for clinical use

To facilitate rapid bedside risk assessment, we developed a simplified scoring system based on the five independent predictors identified in the multivariable analysis and LASSO regression. ROC analysis was used to determine the optimal cutoff for target sign diameter and found the best threshold was 35 mm (Fig. 4). Although the regression coefficients of the five predictors ranged from 0.831 to 1.536 (a maximum-to-minimum ratio of 1.8), we assigned 1 point to each of the five binary high-risk features (transverse colon location, previous history, target sign diameter > 35 mm, peritoneal effusion, and features of enteritis) (Table 3), yielding a total score ranging from 0 to 5. The area under the receiver operating characteristic curve for this simplified score was 0.795 (95% CI: 0.621–0.843), indicating a fine discriminatory ability. Using the Youden index, a cutoff of ≥3 points was identified as the optimal threshold for predicting early recurrence(Fig. 5). This equal-weight approach was chosen to enable immediate bedside calculation without the need for a calculator or nomogram, directly addressing the clinical need for an easy-to-use screening tool. Validation showed that this simplified score retained good discriminatory ability

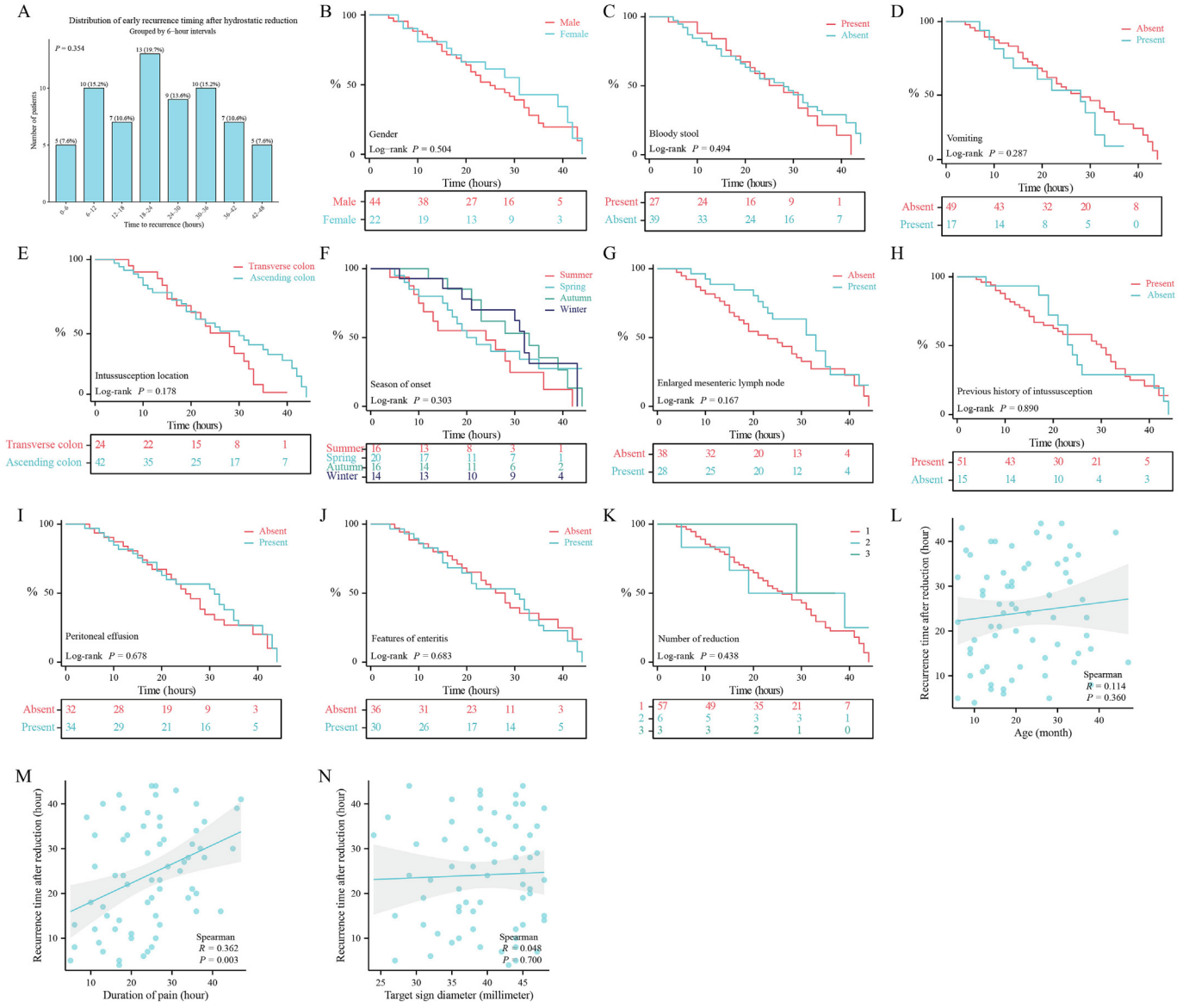

Fig. 2. Characteristics of early recurrence timing. (A) Distribution of recurrence time stratified by 6-h intervals among 66 patients with early recurrence. (B—K) Kaplan-Meier curves comparing recurrence-free survival for categorical variables (sex, bloody stool, vomiting, season, intussusception location, enlarged mesenteric lymph nodes, previous history, peritoneal effusion, features of enteritis, and number of reduction attempts). None of these factors showed a significant association with recurrence time (all log-rank $P > 0.05$). (L–N) Spearman's rank correlation between time to recurrence and continuous variables (age, target sign diameter, and duration of abdominal pain). Only duration of pain showed a weak positive correlation ($R = 0.362$, $P = 0.003$); the other correlations were not significant.

(AUC = 0.795), which was only slightly lower than that of the weighted nomogram (0.805) but substantially more practical for rapid triage. Accordingly, patients with a score of 0–2 are classified as low-risk and may be candidates for abbreviated observation or outpatient follow-up, whereas those with a score of ≥3 are considered high-risk and warrant a full 48-h inpatient observation. This simplified tool provides clinicians with an easy-to-use, visually clear method for rapid risk assessment.

4. Discussion

Ultrasound-guided hydrostatic reduction is increasingly used for pediatric ileocolic intussusception due to its safety and efficacy [6]. In this cohort of 677 children, we observed an early recurrence rate (within 48 h) of 9.7%, which aligns with previous reports [7-9,12]. Although the definition of "early recurrence" varies across studies,ranging from 12 to 72 h, our 48-h cutoff is consistent with Wang et al., who reported that 92.1% of recurrences occur within this window [12]. This consistency suggests that a 48-h observation period captures the vast majority of clinically relevant recurrences.

4.1. Five independent predictors and comparison with previous studies

We identified five independent predictors of early recurrence: transverse colon location, previous history of intussusception, larger target sign diameter, peritoneal effusion, and sonographic features of enteritis. These factors have been variably reported in prior studies. Transverse colon location, for example, has been associated with increased recurrence risk in some studies [20], while others have emphasized the role of more proximal intussusception [21]. Our finding that transverse colon location carried the highest OR may reflect the greater length of bowel involved, which may impair post-reduction peristalsis and predispose to re-invagination.

Previous history of intussusception was a strong predictor in our study, consistent with several earlier reports [12,20]. This suggests

Table 2
Univariate and multivariate analysis of risk factors for early recurrence of intussusception in children.

Characteristics	Univariate analysis		Multivariate analysis	
	Odds Ratio (95% CI)	P value	Odds Ratio (95% CI)	P value
Age	1.016 (0.955–1.038)	0.133		
Gender				
MMMMale	Reference			
Female	0.644 (0.377–1.101)	0.108		
Bloody stool				
Absent	Reference			
Present	0.947 (0.565–1.587)	0.837		
Vomiting				
Absent	Reference			
Present	0.639 (0.359–1.137)	0.128		
Duration of pain	1.035 (1.013–1.057)	0.001	1.032 (1.007–1.058)	0.057
Season of onset				
Winter	Reference			
Spring	1.196 (0.584–2.449)	0.625		
Summer	1.290 (0.607–2.744)	0.508		
Autumn	1.120 (0.528–2.376)	0.767		
Intussusception location				
Ascending colon	Reference		Reference	
Transverse colon	5.104 (2.994–8.702)	<0.001	4.252 (2.412–7.494)	<0.001
Enlarged mesenteric lymph node				
Absent	Reference			
Present	0.789 (0.472–1.319)	0.366		
Previous history of intussusception				
Absent	Reference		Reference	
Present	2.514 (1.337–4.726)	0.004	2.754 (1.339–5.667)	0.006
Target sign diameter	1.070 (1.032–1.110)	<0.001	1.072 (1.030–1.115)	<0.001
Peritoneal effusion				
Absent	Reference		Reference	
Present	2.074 (1.244–3.457)	0.005	2.374 (1.356–4.155)	0.002
Features of enteritis				
Absent	Reference		Reference	
Present	2.966 (1.772–4.965)	<0.001	2.297 (1.311–4.025)	0.004
Number of reduction				
1	Reference			
2	1.260 (0.515–3.079)	0.613		
3	1.050 (0.238–4.638)	0.949		

CI: Confidence interval.

that some children may have an inherent predisposition, possibly related to anatomical or motility factors. Peritoneal effusion and sonographic features of enteritis have been less frequently studied in the context of early recurrence, but both likely indicate more severe inflammation and bowel wall edema, which may delay healing and increase recurrence risk [14,22]. The target sign diameter, which reflects the thickness and number of invaginated layers, has been shown to correlate with failed reduction and recurrence in other studies [21], and our findings further support its prognostic value.

4.2. Age and symptom duration

Although age and symptom duration were also independent predictors in our univariable model, but not independent predictors in multivariate analysis, so they were not included in the final simplified tool because their effect sizes were smaller. Age > 1 year has been previously identified as a risk factor for early recurrence [20], which may be explained by the dynamic changes in gut microbiota during early childhood [23]. Stewart et al. described three phases of gut microbiome maturation, with the transitional phase (15–30 months) coinciding with our recurrence group's median age of 19 months [24]. This temporal overlap suggests that immune and microbial instability during this period may increase susceptibility to inflammation and recurrence. Longer symptom duration, another known predictor of failed reduction [21,25], may reflect delayed presentation and more advanced local inflammation, which could predispose to recurrence even after successful reduction.

4.3. Dissociation between recurrence occurrence and timing

A notable finding is that while the five predictors strongly discriminated patients who would recur from those who would not, none significantly influenced the exact timing of recurrence. To our knowledge, this dissociation has not been reported previously. This suggests that the mechanisms driving susceptibility to recurrence (e.g., structural, inflammatory factors) are distinct from those triggering the actual event (e.g., dynamic processes such as peristalsis recovery or patient activity). Clinically, this means that once a patient is identified as high-risk, a uniform 48-h observation period is appropriate, regardless of when recurrence might occur. This simplifies post-reduction management and supports a risk-stratified approach.

4.4. Temporal distribution and clinical implications

The median recurrence time in our cohort was 23 h, with only 7.6% occurring within the first 6 h and nearly half (47.0%) occurring between 24 and 48 h. This distribution is similar to that reported by Wang et al. (median 21 h) [12], suggesting that the temporal course of early recurrence is relatively consistent across different populations and reduction techniques. The proportion of very early recurrences (≤6 h) in our cohort (7.6%) is comparable to the 3.5% reported by Wang et al., with the difference likely reflecting variations in reduction technique (hydrostatic vs. pneumatic), case mix, or post-reduction observation protocols.

From a clinical perspective, these findings have important implications for emergency department disposition. A short observation period (e.g., 4–6 h) would miss the majority of early recurrences, whereas a full

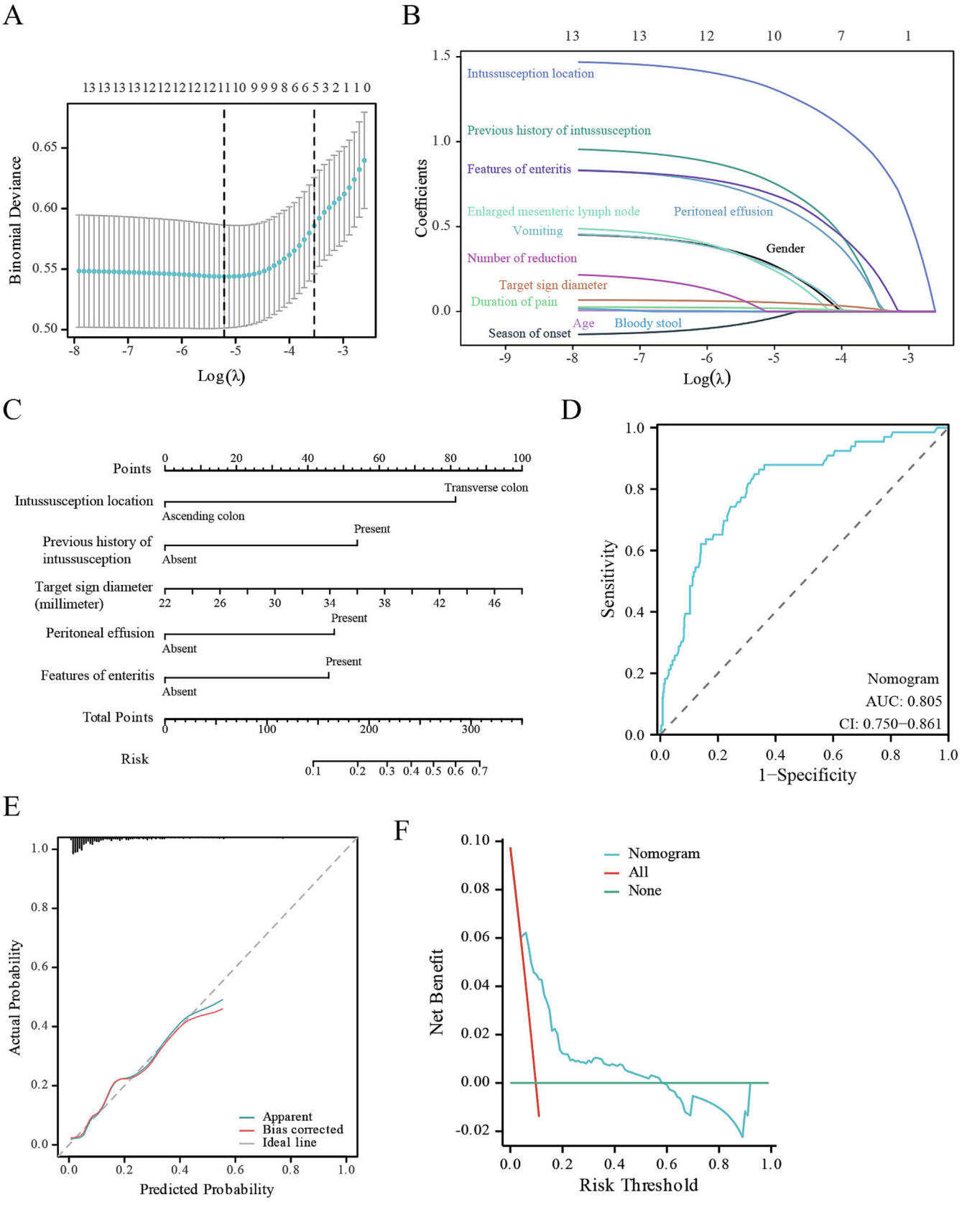

Fig. 3. Construction and validation of the nomogram. (A) LASSO regression with 10-fold cross-validation showing binomial deviance as a function of log(λ). The left vertical dashed line indicates λ with minimum deviance; the right dashed line indicates λ.1se, which retained 5 non-zero coefficients. (B) Coefficient paths for 13 candidate variables across the same λ range. (C) Nomogram for predicting early recurrence based on five independent predictors (transverse colon location, previous history, target sign diameter, peritoneal effusion, and features of enteritis). To calculate the predicted probability, locate each predictor on its axis, draw a vertical line to the "Points" axis to obtain the score, sum the scores, and read the corresponding probability from the "Total Points" axis. (D) Receiver operating characteristic (ROC) curve of the nomogram (AUC = 0.805; 95% CI: 0.750–0.861). (E) Calibration plot showing agreement between predicted and observed probabilities. (F) Decision curve analysis demonstrating net benefit across a range of threshold probabilities.

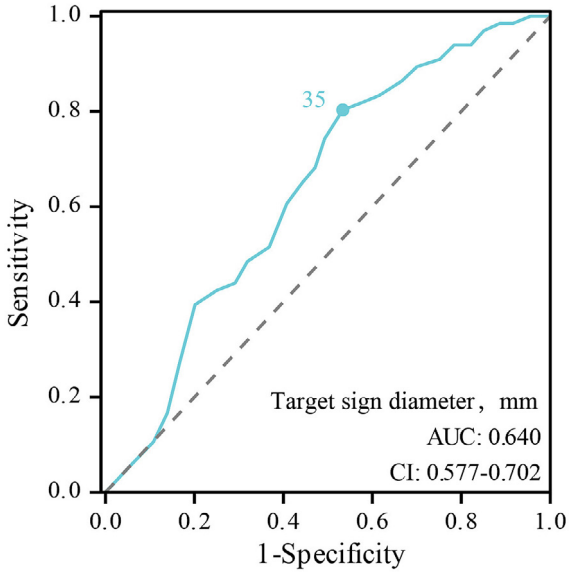

Fig. 4. ROC curve for target sign diameter, identifying 35 mm as the optimal cutoff.

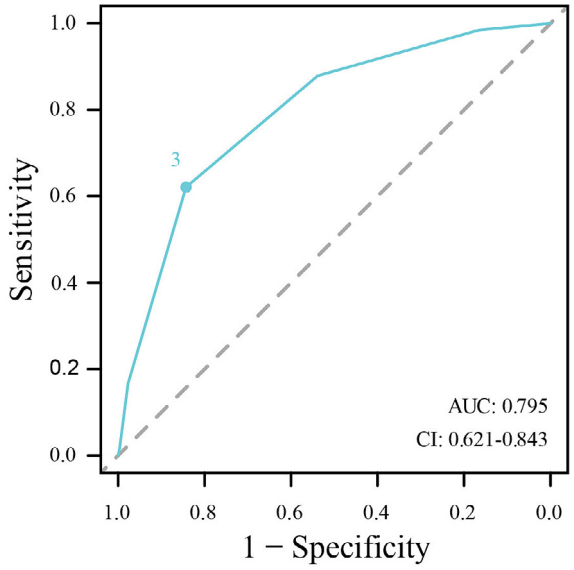

Fig. 5. ROC curve for the simplified score (0–5) derived from the five high-risk features, showing an AUC of 0.795 (95% CI: 0.621–0.843). The optimal cutoff is 3 points.

48-h observation would capture all cases. This supports a risk-stratified approach: low-risk patients (simplified score 0–2) could be candidates for abbreviated observation (e.g., 12–24 h) or outpatient follow-up, while high-risk patients (score ≥ 3) warrant a full 48-h inpatient observation.

4.5. A dual-tool approach for clinical risk stratification

To translate these findings into practice, we developed two complementary tools. The nomogram provides individualized probability estimates by weighting each predictor according to its regression coefficient. This tool is suitable for nuanced decision-making, such as counseling families or managing borderline cases. Recognizing the need for rapid bedside screening, we also developed a simplified score that assigns 1 point to each of the five binary high-risk features. This equal-weight approach, while sacrificing some precision, enables immediate mental calculation and is consistent with the design of many widely adopted clinical scores. The simplified score demonstrated good discriminatory ability (AUC 0.795), and a cutoff of 3 points optimally balanced sensitivity (62.1%) and specificity (84.3%).

4.6. Limitations and future directions

Several limitations should be acknowledged. First, this was a single-center retrospective study, which may introduce selection bias. Second, laboratory markers (e.g., C-reactive protein) were not assessed; incorporating them might improve prediction. Third, our definition of early recurrence as within 48 h, while consistent with previous literature, may not be universally accepted. Fourth, only internal validation was performed; external validation is needed to confirm generalizability.

Table 3
Regression coefficients of the five predictors.

Predictor	Regression coefficient(β)
Transverse colon location	1.536
Previous history	1.022
Target sign diameter > 35 mm	1.166
Peritoneal effusion	0.922
Features of enteritis	0.831

Future multicenter prospective studies with external validation are warranted to confirm our findings and to explore whether these risk factors apply to pneumatic reduction, which differs in technique and pressure dynamics.

5. Conclusion

Based on five independent predictors of early recurrence following ultrasound-guided hydrostatic reduction of pediatric ileocolic intussusception (transverse colon location, previous history of intussusception, target sign diameter > 35 mm, peritoneal effusion, and sonographic features of enteritis), we developed two complementary clinical tools. The nomogram provides individualized probability estimates for nuanced decision-making, while a simplified bedside score (0–5) enables rapid risk stratification, with a cutoff of 3 points effectively distinguishing high-risk from low-risk patients. Early recurrence is distributed across the 48-h observation window, and importantly, the factors predicting recurrence do not influence its timing, supporting a uniform observation strategy for high-risk patients. Together, these tools offer clinicians a practical, evidence-based approach to post-reduction management that balances patient safety with efficient resource use.

CRediT authorship contribution statement

Zhaozheng Ding: Data curation. **Hongjia Qiang:** Data curation, Conceptualization. **Xin Li:** Data curation. **Xiangjie Li:** Data curation. **Yuan Cao:** Supervision. **Dongsheng Zhu:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Consent to participate

Written informed consent was obtained from all legal guardians of the children prior to their participation in the study.

Ethical approval

The present study was approved by the Ethics Committee of the First People's Hospital of Lianyungang.

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Declaration of competing interest

The authors have declared that no competing interests exist.

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Not applicable.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2026.04.014.

Data availability

The datasets used during this study are available from the corresponding author on reasonable request.

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