Journal of Kyzylorda Scholarly Review

P-ISSN:3006-0265 | E-ISSN:3007-4681. Published by the Open University of Kyzylorda
Copyright © Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC-BY).
https://bulletin.ouk.kz/index.php/bulletin/index



CLINICAL AND ULTRASONOGRAPHIC FACTORS ASSOCIATED WITH FAILED ENEMA REDUCTION IN PEDIATRIC INTUSSUSCEPTION

Akram Jooda Al Zaidy[*1]
[1]College of Medicine, Al-Ayen Iraqi University, AUIQ, Thi-Qar, Iraq
[*]Correspondance: mtqr86@gmail.com

Article History:
Received: 30th Sept 2026; Revised: 20th Oct 2026; Accepted: 10th Nov 2026; Published: 25th Nov 2026

Abstract: Background: Enema reduction is the first-line treatment for intussusception in haemodynamically stable children, but some children still need an operation. Recognising them early could limit futile attempts and speed surgical referral. **Objective:** To identify clinical, laboratory and ultrasonographic factors associated with failed enema reduction. **Methods:** In this retrospective case–control study at four hospitals in Dhi Qar Governorate, Iraq (September 2025 to April 2026), 30 children with failed enema reduction were compared with 30 children with successful reduction. Firth penalised logistic regression was used because several predictors separated the groups completely. Three pre-specified three-variable models (clinical, ultrasonographic and combined) were evaluated by the area under the receiver operating characteristic curve (AUC), with bootstrap optimism correction. **Results:** Age, sex, weight and enema modality were similar between groups. Failure was associated with longer symptom duration (43.5 ± 13.3 vs 17.8 ± 7.9 h), bloody stool (76.7% vs 10.0%), lethargy (63.3% vs 20.0%), a higher white-cell count and lactate (2.37 vs 1.55 mmol/L), a longer (56.2 vs 37.8 mm) and wider intussusception, trapped fluid (56.7% vs 0%) and reduced or absent Doppler flow (70.0% vs 30.0%) (all $p < 0.01$). Symptom duration of 26 h or more discriminated best (AUC 0.95; sensitivity 93.3%, specificity 86.7%). Independent factors were symptom duration (adjusted odds ratio [aOR] 7.4 per 12 h) and bloody stool (aOR 26.5) in the clinical model, and intussusceptum length (aOR 6.4 per 10 mm), trapped fluid (aOR 15.9) and impaired Doppler flow (aOR 6.6) in the ultrasonographic model. A three-item score (symptoms ≥ 26 h, length ≥ 48 mm, trapped fluid) of 2 or more had a sensitivity of 93.3% and a specificity of 96.7%. **Conclusion:** Late presentation, rectal bleeding, a long intussusceptum, trapped fluid and impaired Doppler flow identify children at high risk of failed enema reduction, who may benefit from early surgical involvement. The score needs prospective validation before clinical use.

Keywords: intussusception, enema reduction, ultrasonography, trapped fluid, Doppler, treatment failure, children

Introduction

Intussusception is the leading cause of acute intestinal obstruction in infants and toddlers. A review of 82 studies published after 2002 reported a mean incidence of 74 per 100,000 children younger than one year, with a peak between 5 and 7 months of age [1]. Most childhood cases are idiopathic and ileocolic. Ultrasonography has replaced plain radiography and contrast studies as the first diagnostic step, because it is accurate, free of radiation and able to show features that bear on management [2,3].

In a child without peritonitis, perforation or shock, the accepted first treatment is enema reduction with air or liquid under fluoroscopic or sonographic guidance [4–6]. Reported success varies widely. A meta-analysis of more than 30,000 children found pooled success rates of 82.7% for air enema and 69.6% for liquid enema [7]. Individual centres have reported anything from 46% to 94% [8], and a 20-year experience with ultrasound-guided saline enema achieved success in 83% of reductions [9]. Children in whom reduction fails need an operation, often after several attempts. They face a longer hospital stay, a risk of bowel resection and, with repeated high-pressure attempts on non-viable bowel, a risk of perforation [10,11].

It would therefore help to know, before the enema begins, which children are unlikely to respond. A 2021 meta-analysis pooled the available evidence. A symptom duration below 24 h favoured success, whereas age under one year, fever, vomiting, rectal bleeding, ascites, a left-sided intussusception and trapped fluid on ultrasonography favoured failure [12]. Other cohorts have pointed to lethargy, diarrhoea and a distal position of the intussusception [13]. Sonographic signs have drawn particular attention. Fluid trapped between the layers of the intussusception was linked to irreducibility and ischaemia more than 25 years ago [14], and a later multicentre series found that a fluid collection of 9 mm or more carried a markedly higher failure rate [15]. Loss of colour Doppler signal in the intussusceptum has been associated with non-viable bowel [16], and the combination of free fluid, small-bowel obstruction and trapped fluid has been used to stratify the likely outcome of air enema [17]. Studies of ultrasound-guided saline reduction have reported similar risk factors [18,19]. More recently, symptoms lasting longer than 24 h were associated with failed sonographically guided saline enema in a German series [20], and Chinese groups have built nomograms that combine clinical, laboratory and sonographic variables [21,22].

Most of this evidence comes from East Asia, Europe and North America. Data from Iraq are scarce and largely descriptive [23], although late presentation and uneven access to paediatric imaging and surgery are common in the region. Few studies have also assessed clinical, laboratory and ultrasonographic variables together while using statistical methods suited to small samples with strongly separating predictors. We therefore set out to identify the clinical and ultrasonographic factors associated with failed enema reduction in children treated at four hospitals in southern Iraq, and to estimate how well these factors, alone and in combination, discriminate between failed and successful reduction.

Materials and methods

Study design and setting

This retrospective, multicentre case–control study was carried out at four public hospitals in Dhi Qar Governorate, southern Iraq: Al-Nasiriyah Teaching Hospital, Al-Rifai Hospital, Al-Shatrah Hospital and Al-Wilada Hospital. Records of children treated between September 2025 and April 2026 were reviewed. The report follows the STROBE recommendations for case–control studies [24].

Participants

Children were eligible if they had intussusception confirmed on ultrasonography, met the Brighton Collaboration level 1 diagnostic criteria [25] and underwent at least one attempt at enema reduction. Children with clinical or radiological signs of peritonitis or perforation, haemodynamic instability, or a primary operation without an enema attempt were excluded, as were children whose records lacked the outcome of reduction or the core sonographic

variables. Of 78 children assessed for eligibility, 18 (23.1%) were excluded on these grounds and 60 were included (Figure 1).

All consecutive eligible children whose enema reduction failed during the study period were included as cases (n = 30). Controls were children with successful enema reduction treated at the participating hospitals during the same period. They were selected in a 1:1 ratio by simple random sampling, using computer-generated random numbers applied to the hospital registers (n = 30). Controls were not matched to cases, so that age, sex and other baseline characteristics could be examined as potential predictors rather than being fixed by design. Figure 1 shows the flow of participants.

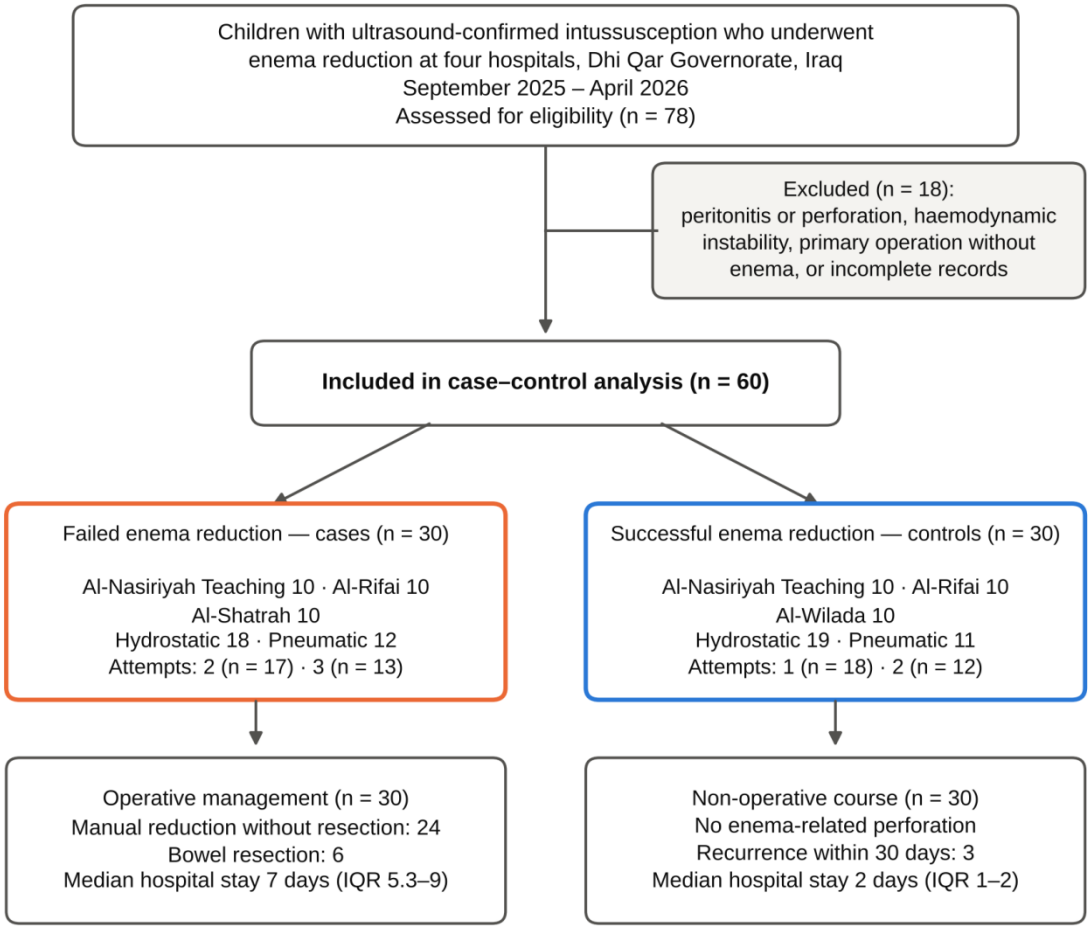


Figure 1. Flow of participants through the study. Cases were children whose enema reduction failed; controls were children whose reduction succeeded. Eighteen of the 78 children assessed for eligibility were excluded.

Data collection

[Two investigators] extracted data onto a standard form. Demographic variables were age, sex, weight and residence. Clinical variables, recorded at presentation, were symptom duration (from the first episode of pain or crying to the first enema), vomiting episodes per day, bilious vomiting, intermittent abdominal pain, bloody (red-currant-jelly) stool, palpable abdominal mass, abdominal distension, fever of 38 °C or more, degree of dehydration (none, mild, moderate or severe on clinical assessment), lethargy and previous intussusception. Laboratory variables were total white-cell count, neutrophil percentage, C-

reactive protein (CRP), serum sodium, potassium and venous lactate, all drawn before the enema.

Ultrasonographic assessment

Ultrasonography was performed by [radiologists / sonologists with ≥ x years of paediatric experience] using [scanner model] with a [frequency] MHz linear transducer, supplemented by a curvilinear probe when needed. Standard definitions were applied [3,26] (Figure 2):

- **Type and location:** ileocolic, ileoileocolic or colocolic, and the quadrant in which the head of the intussusception lay.
- **Transverse diameter:** the largest outer diameter of the target (doughnut) image, in millimetres.
- **Length:** the longest longitudinal extent of the intussusception on the pseudokidney view, in millimetres.
- **Outer wall thickness:** the thickness of the outer hypoechoic ring, in millimetres.
- **Trapped fluid:** an anechoic or crescentic fluid collection between the serosal layers of the intussusceptum and intussuscipiens, inside the mass.
- **Free peritoneal fluid:** fluid outside the intussusception, between bowel loops or in the pelvis.
- **Doppler vascularity:** colour Doppler signal in the wall and mesentery of the intussusceptum, graded as preserved, reduced or absent.
- **Other findings:** bowel wall oedema, enlarged mesenteric lymph nodes within the mass, a suspected pathological lead point, and small-bowel obstruction (dilated, fluid-filled small-bowel loops proximal to the intussusception).

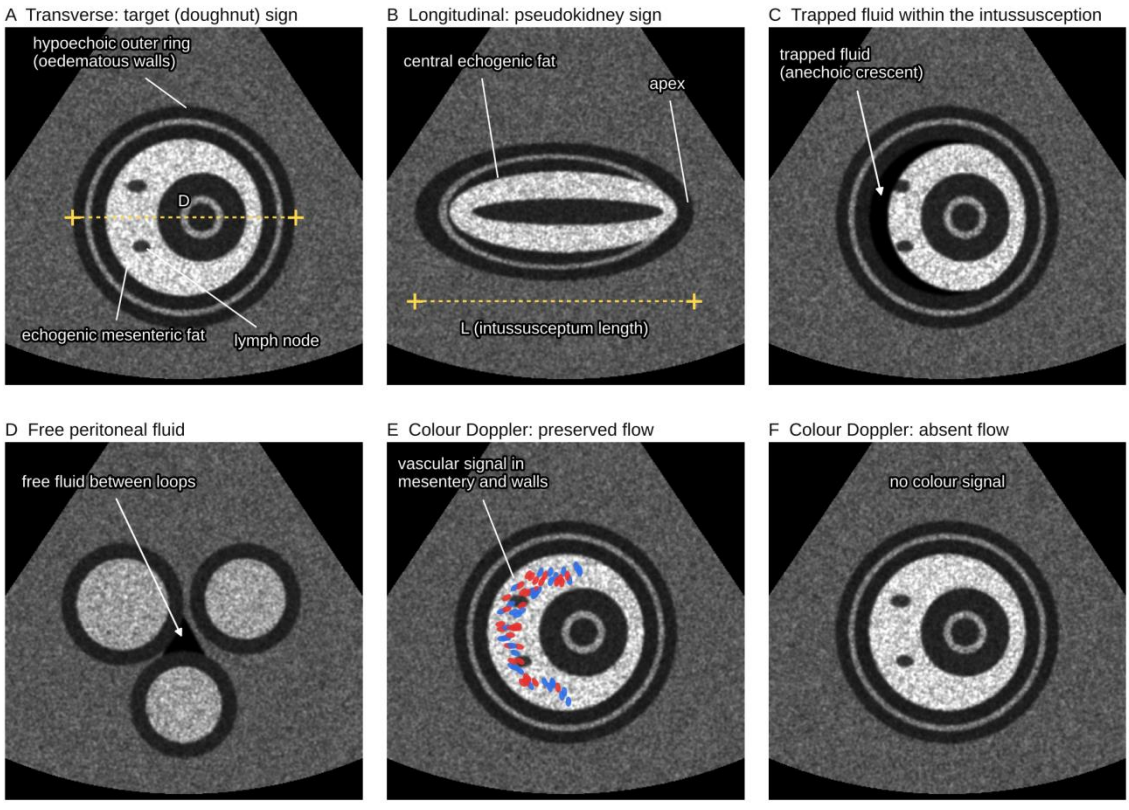


Figure 2. Schematic illustration of the sonographic features assessed. (A) Transverse target sign with the hypoechoic outer ring, echogenic mesenteric fat, a mesenteric lymph node and

measurement of the transverse diameter (D). (B) Longitudinal pseudokidney view with measurement of length (L). (C) Trapped fluid, seen as an anechoic crescent between the layers of the intussusception. (D) Free peritoneal fluid between bowel loops. (E) Preserved colour Doppler signal in the mesentery and walls. (F) Absent colour Doppler signal.

Enema reduction

Reduction was attempted after resuscitation with intravenous fluids, correction of electrolyte disturbances and analgesia, with sedation as clinically appropriate. Pneumatic reduction was performed under intermittent fluoroscopic guidance with a manometer-controlled insufflator. The intraluminal pressure started at 80 mmHg and was raised stepwise to a maximum of 120 mmHg, which was not exceeded [8]. Hydrostatic reduction used warm normal saline under continuous real-time ultrasonographic guidance. The saline reservoir was placed about 100 cm above the table and raised, if needed, to a maximum of 120 cm (about 88 mmHg) [6]. For both techniques, up to three attempts of about 3 minutes each were made, separated by 3-minute rest periods (the "rule of threes") [8]. The procedure was stopped after fewer attempts if the intussusception did not move on successive attempts or the child's condition worsened. Reduction was judged complete when the mass disappeared and saline or air passed freely into the terminal ileum. Total enema time was recorded from insertion of the rectal catheter to the end of the procedure, including rest intervals and confirmatory imaging. The choice of modality followed the treating team and the equipment available at each hospital.

Outcome

The primary outcome was failed enema reduction, defined as persistence of the intussusception after the maximum permitted number of attempts, leading to operative management. Secondary outcomes were bowel resection, length of hospital stay, complications and recurrence within 30 days.

Statistical analysis

Continuous variables were checked for normality with the Shapiro–Wilk test. Approximately normal variables are reported as mean ± standard deviation (SD) and compared with Welch's t-test. Skewed variables are reported as median (interquartile range, IQR) and compared with the Mann–Whitney U test. Categorical variables are given as number (%) and compared with Fisher's exact test, or the Fisher–Freeman–Halton exact test for tables larger than 2 × 2. The Cochran–Armitage test assessed trends across ordered categories (dehydration grade and Doppler vascularity).

Several binary predictors were never present in the control group, so ordinary maximum-likelihood logistic regression could not produce finite estimates. We therefore used Firth's penalised likelihood logistic regression for all univariable and multivariable models [27,28]. Confidence intervals were obtained from the profile penalised likelihood and p values from penalised likelihood-ratio tests. With 30 events, models were limited to three predictors, giving about ten events per variable [29]. Three models were pre-specified. Model 1 (clinical) included symptom duration, bloody stool and lethargy. Model 2 (ultrasonographic) included intussusceptum length, trapped fluid and reduced or absent Doppler flow. Model 3 (combined) included symptom duration, intussusceptum length and trapped fluid. Candidate variables were chosen for clinical plausibility, strength of univariable association and low mutual correlation. Continuous predictors were entered per 12 h (symptom duration) and per 10 mm (length) to aid interpretation.

Discrimination was measured by the AUC with 95% confidence intervals (CIs) by DeLong's method, and correlated AUCs were compared with the DeLong test [30]. The optimal cut-off for each continuous predictor was chosen by the maximum Youden index [31]. Sensitivity and specificity are reported with Wilson 95% CIs. Because cases and controls were sampled in equal numbers, predictive values reflect a 50% prevalence and do not apply directly to unselected patients. Model optimism was estimated with 500 bootstrap resamples, refitting the full model in each, and subtracted from the apparent AUC [32]. Overall accuracy was summarised by the Brier score. A simple point score was formed from the three predictors of Model 3, each dichotomised at its Youden cut-off. Because two hospitals contributed only cases or only controls, a sensitivity analysis repeated the main analyses in the 40 children from the two hospitals that contributed both groups.

All tests were two-sided, with $p < 0.05$ taken as significant. Given the number of comparisons, p values for secondary variables should be read as exploratory. Analyses were run in Python 3.13 with NumPy 2.5, pandas 3.0 and SciPy 1.18. Firth regression, DeLong tests and the exact tests were coded following the cited methods. The analysis code is available from the corresponding author.

Ethical approval

The study was approved by the institutional research ethics committee (approval no. AUIQ-20261117). Because only anonymised routine records were used, the requirement for informed consent was waived.

Results

Study population

Of 78 children assessed for eligibility, 18 were excluded, and 60 were analysed: 30 with failed and 30 with successful enema reduction (Figure 1). Their median age was 23.5 months (IQR 13.3–30.0), 15 (25.0%) were younger than one year, and 32 (53.3%) were boys. The two groups were similar in age, sex, weight, residence and history of intussusception (Table 1). Hydrostatic reduction was used in 37 children (61.7%) and pneumatic reduction in 23 (38.3%). Failure was as frequent after hydrostatic as after pneumatic enema (18/37, 48.6% vs 12/23, 52.2%; p = 1.000). Al-Shatrah Hospital contributed only cases and Al-Wilada Hospital only controls.

Table 1. Demographic and baseline characteristics by outcome of enema reduction

Characteristic	Failed (n = 30)	Successful (n = 30)	p value
Age, months, median (IQR)	23.0 (17.0–29.0)	24.5 (10.0–30.8)	0.853[a]
Age < 12 months, n (%)	6 (20.0)	9 (30.0)	0.552[b]
Male sex, n (%)	17 (56.7)	15 (50.0)	0.796[b]
Weight, kg, mean ± SD	7.96 ± 1.96	7.85 ± 2.11	0.835[c]
Rural residence, n (%)	20 (66.7)	17 (56.7)	0.596[b]
Previous intussusception, n (%)	3 (10.0)	2 (6.7)	1.000[b]
Enema modality, n (%)			1.000[b]
Hydrostatic (saline, US-guided)	18 (60.0)	19 (63.3)	
Pneumatic (air, fluoroscopic)	12 (40.0)	11 (36.7)	
Hospital, n (%)			< 0.001[d]

Al-Nasiriyah Teaching Hospital	10 (33.3)	10 (33.3)
Al-Rifai Hospital	10 (33.3)	10 (33.3)
Al-Shatrah Hospital	10 (33.3)	0 (0.0)
Al-Wilada Hospital	0 (0.0)	10 (33.3)

[a] Mann–Whitney U test; [b] Fisher's exact test; [c] Welch's t-test; [d] Fisher–Freeman–Halton exact test. IQR, interquartile range; SD, standard deviation; US, ultrasound.

Clinical and laboratory findings

Children whose reduction failed had been unwell for more than twice as long as those whose reduction succeeded (mean 43.5 ± 13.3 vs 17.8 ± 7.9 h; $p < 0.001$). Twenty-eight of the 30 cases (93.3%) presented after 24 h, compared with 4 of 30 controls (13.3%). Bloody stool (76.7% vs 10.0%), lethargy (63.3% vs 20.0%), a palpable mass (60.0% vs 30.0%) and the full classic triad (46.7% vs 3.3%) were all more common in the failed group (Table 2). Dehydration rose in severity with failure: no child in the failed group was free of dehydration, and severe dehydration occurred only in that group (p for trend < 0.001). Fever, bilious vomiting and intermittent pain did not differ.

Among laboratory tests, the failed group had a higher white-cell count (14.8 ± 3.0 vs 10.7 ± 3.1 × 10^9/L), CRP (median 17.4 vs 9.2 mg/L) and venous lactate (2.37 ± 0.54 vs 1.55 ± 0.47 mmol/L), all $p \leq 0.004$. Neutrophil percentage, sodium and potassium were similar (Table 2; Figure 3).

Table 2. Clinical presentation and laboratory findings by outcome of enema reduction

Variable	Failed (n = 30)	Successful (n = 30)	p value
Clinical			
Symptom duration, h, mean ± SD	43.5 ± 13.3	17.8 ± 7.9	< 0.001[c]
Symptom duration > 24 h, n (%)	28 (93.3)	4 (13.3)	< 0.001[b]
Vomiting episodes per day, median (IQR)	5 (4–7)	4 (2–5)	< 0.001[a]
Bilious vomiting, n (%)	6 (20.0)	2 (6.7)	0.254[b]
Intermittent abdominal pain, n (%)	24 (80.0)	27 (90.0)	0.472[b]
Bloody stool, n (%)	23 (76.7)	3 (10.0)	< 0.001[b]
Palpable abdominal mass, n (%)	18 (60.0)	9 (30.0)	0.037[b]
Classic triad (pain, mass, bloody stool), n (%)	14 (46.7)	1 (3.3)	< 0.001[b]
Abdominal distension, n (%)	18 (60.0)	10 (33.3)	0.069[b]
Fever ≥ 38 °C, n (%)	4 (13.3)	4 (13.3)	1.000[b]
Lethargy, n (%)	19 (63.3)	6 (20.0)	0.001[b]
Dehydration, n (%)			< 0.001[d]
None	0 (0.0)	11 (36.7)	
Mild	10 (33.3)	12 (40.0)	
Moderate	13 (43.3)	7 (23.3)	
Severe	7 (23.3)	0 (0.0)	
Laboratory			

White-cell count, × 10^9/L, mean ± SD	14.8 ± 3.0	10.7 ± 3.1	< 0.001[c]
Neutrophils, %, median (IQR)	62.0 (58.2–75.0)	64.5 (54.2–76.8)	0.762[a]
C-reactive protein, mg/L, median (IQR)	17.4 (12.8–23.3)	9.2 (1.9–18.7)	0.004[a]
Sodium, mmol/L, median (IQR)	137.5 (134.0–141.8)	139.5 (137.0–142.0)	0.117[a]
Potassium, mmol/L, mean ± SD	4.07 ± 0.47	4.04 ± 0.35	0.782[c]
Lactate, mmol/L, mean ± SD	2.37 ± 0.54	1.55 ± 0.47	< 0.001[c]

[a] Mann–Whitney U test; [b] Fisher's exact test; [c] Welch's t-test; [d] Fisher–Freeman–Halton exact test (Cochran–Armitage test for trend, p < 0.001).

Ultrasonographic findings

The type and position of the intussusception did not differ between groups; ileocolic intussusception predominated in both (70.0% and 80.0%). The intussusception was larger in the failed group in every dimension measured. Its mean length was 56.2 ± 8.2 mm versus 37.8 ± 9.5 mm, its transverse diameter 34.5 ± 5.8 mm versus 27.2 ± 4.5 mm, and its outer wall 5.3 ± 1.0 mm versus 4.0 ± 1.0 mm thick (all p < 0.001; Table 3, Figure 3).

Trapped fluid was seen in 17 children whose reduction failed (56.7%) and in none whose reduction succeeded. A suspected lead point showed the same one-sided pattern (6 vs 0). Doppler flow was reduced or absent in 21 failed cases (70.0%) and 9 controls (30.0%), and all 5 children with absent flow failed reduction. Free peritoneal fluid, bowel wall oedema and small-bowel obstruction were also more frequent after failure, whereas enlarged mesenteric lymph nodes were not (Table 3; Figure 4).

Table 3. Ultrasonographic findings by outcome of enema reduction

Finding	Failed (n = 30)	Successful (n = 30)	p value
Type, n (%)			0.490[d]
Ileocolic	21 (70.0)	24 (80.0)	
Ileoileocolic	8 (26.7)	4 (13.3)	
Colocolic	1 (3.3)	2 (6.7)	
Location of the head, n (%)			0.804[d]
Right upper quadrant	10 (33.3)	13 (43.3)	
Right lower quadrant	11 (36.7)	10 (33.3)	
Central abdomen	9 (30.0)	7 (23.3)	
Transverse diameter, mm, mean ± SD	34.5 ± 5.8	27.2 ± 4.5	< 0.001[c]
Length, mm, mean ± SD	56.2 ± 8.2	37.8 ± 9.5	< 0.001[c]
Outer wall thickness, mm, mean ± SD	5.3 ± 1.0	4.0 ± 1.0	< 0.001[c]
Free peritoneal fluid, n (%)	24 (80.0)	13 (43.3)	0.007[b]
Trapped fluid, n (%)	17 (56.7)	0 (0.0)	< 0.001[b]
Enlarged mesenteric lymph nodes, n (%)	18 (60.0)	14 (46.7)	0.438[b]
Doppler vascularity, n (%)			0.002[d]
Preserved	9 (30.0)	21 (70.0)	
Reduced	16 (53.3)	9 (30.0)	

Absent	5 (16.7)	0 (0.0)	
Bowel wall oedema, n (%)	21 (70.0)	8 (26.7)	0.002[b]
Suspected pathological lead point, n (%)	6 (20.0)	0 (0.0)	0.024[b]
Small-bowel obstruction, n (%)	19 (63.3)	9 (30.0)	0.019[b]

[b] Fisher's exact test; [c] Welch's t-test; [d] Fisher–Freeman–Halton exact test (Doppler: Cochran–Armitage test for trend, p < 0.001).

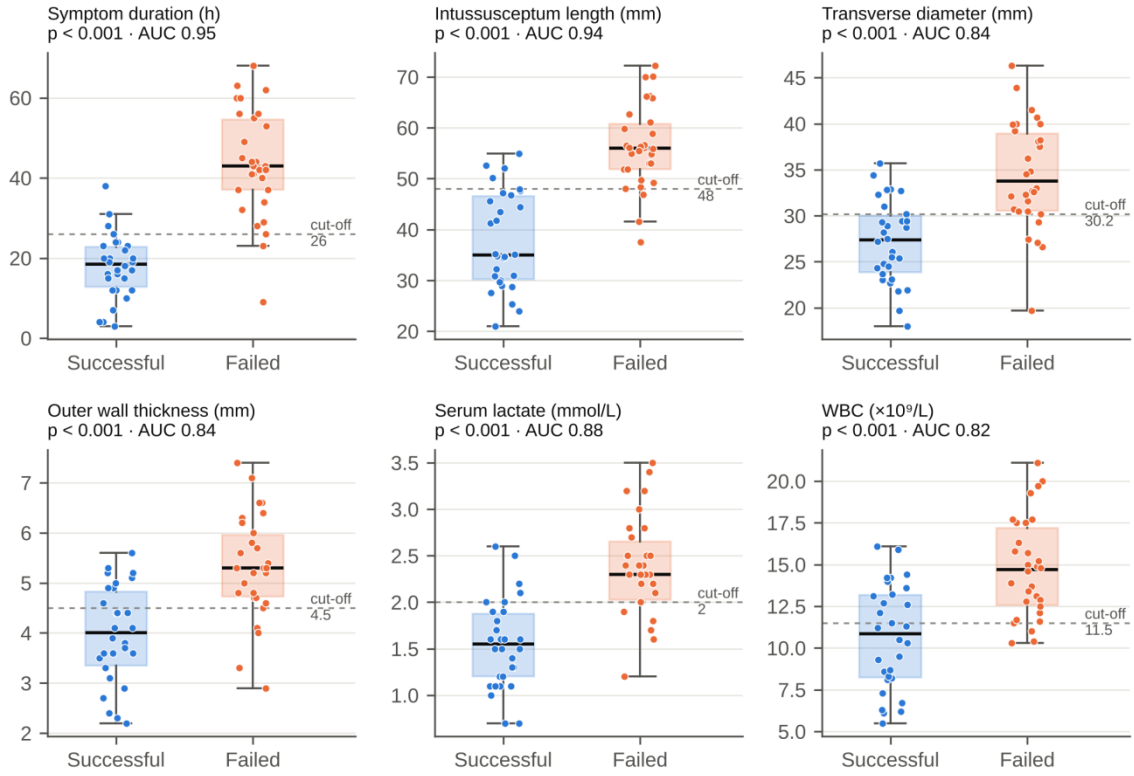


Figure 3. Continuous clinical, laboratory and sonographic variables by outcome of enema reduction. Boxes show the median and interquartile range, whiskers the range and dots individual children. Dashed lines mark the Youden-optimal cut-offs. P values are from Welch's t-test. AUC, area under the receiver operating characteristic curve; WBC, white-cell count.

Univariable and multivariable analysis

In univariable Firth regression, the strongest clinical associations were bloody stool (OR 24.6, 95% CI 6.8–114), lethargy (OR 6.4, 2.2–21.1) and moderate or severe dehydration (OR 6.1, 2.1–19.6). The strongest sonographic association was trapped fluid (OR 79.1, 9.5–10,349); its very wide interval reflects the absence of this sign among controls (Figure 4). Each additional 12 h of symptoms multiplied the odds of failure about tenfold, and each additional 10 mm of length about ninefold (Table 4).

Journal of Kyzylorda Scholarly Review
P-ISSN:3006-0265 | E-ISSN:3007-4681
https://bulletin.ouk.kz/index.php/bulletin/index

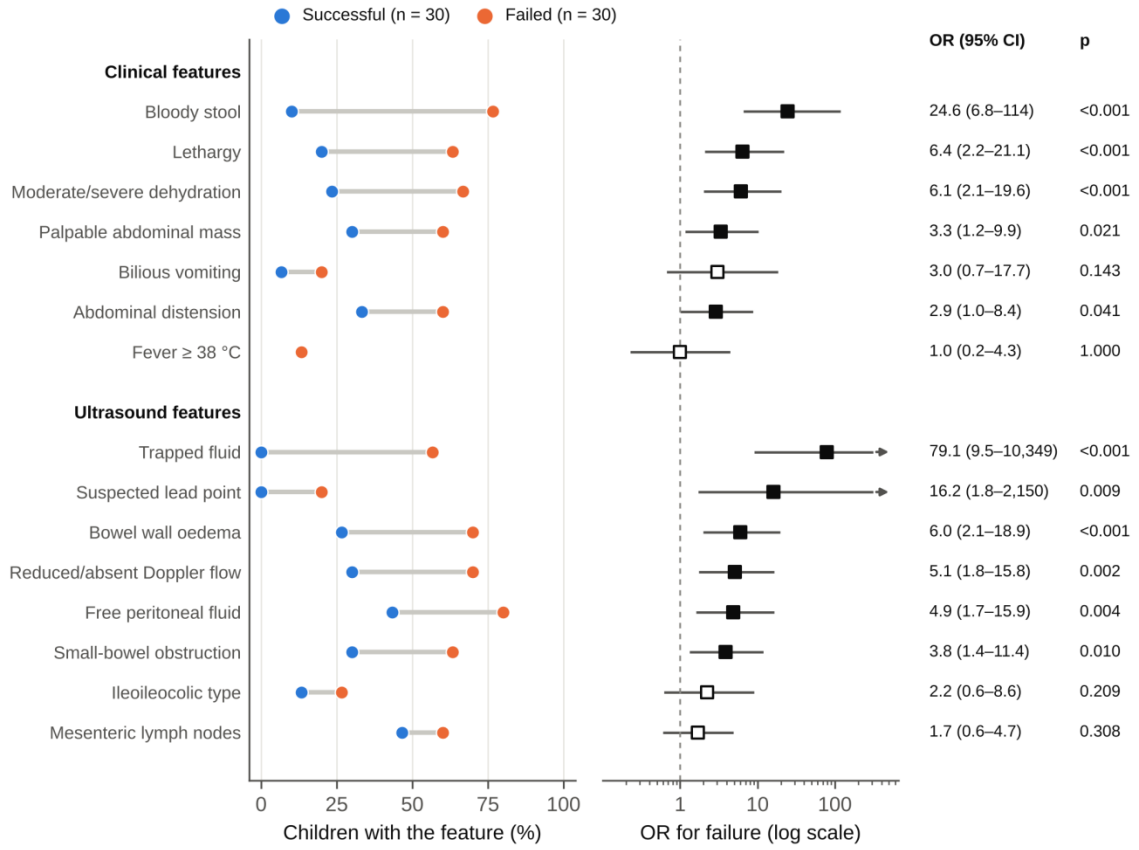


Figure 4. Prevalence of clinical and sonographic features in each group (left) and univariable Firth odds ratios for failed reduction with 95% profile-likelihood confidence intervals (right). Filled squares mark intervals that exclude 1; arrows mark upper limits beyond the plotted range. Fever was present in four children in each group, so the two markers overlap.

In Model 1, symptom duration (adjusted OR [aOR] 7.4 per 12 h, 2.4–44.5) and bloody stool (aOR 26.5, 2.7–905) remained independently associated with failure, whereas lethargy did not (aOR 3.8, 0.5–36.2). In Model 2, intussusceptum length (aOR 6.4 per 10 mm, 2.3–31.3), trapped fluid (aOR 15.9, 1.3–2,252) and reduced or absent Doppler flow (aOR 6.6, 1.1–69.4) were each independently associated with failure. In Model 3, symptom duration kept its effect (aOR 12.4 per 12 h, 2.9–486), trapped fluid was of borderline significance (aOR 136.8; p = 0.052), and length lost its independent effect (aOR 2.1, 0.2–30.5). Length and duration were moderately correlated (Spearman ρ = 0.57), which may explain the attenuation (Table 4; Figure 5).

Table 4. Firth penalised logistic regression for failed enema reduction

Predictor (unit)	β	OR (95% CI)	p value
A. Univariable, continuous predictors			
Symptom duration (per 12 h)	2.31	10.09 (3.90–41.69)	< 0.001
Intussusceptum length (per 10 mm)	2.18	8.83 (3.48–37.05)	< 0.001
Transverse diameter (per 5 mm)	1.29	3.63 (1.98–8.10)	< 0.001
Outer wall thickness (per 1 mm)	1.31	3.69 (1.96–8.39)	< 0.001
Lactate (per 1 mmol/L)	3.08	21.74 (5.53–135.06)	< 0.001
White-cell count (per 1 × 10^9/L)	0.43	1.53 (1.25–2.01)	< 0.001
C-reactive protein (per 10 mg/L)	0.82	2.28 (1.29–4.38)	0.004
Vomiting (per episode/day)	0.70	2.02 (1.41–3.26)	< 0.001

Journal of Kyzylorda Scholarly Review
P-ISSN:3006-0265 | E-ISSN:3007-4681
https://bulletin.ouk.kz/index.php/bulletin/index

Age (per 6 months)	0.06	1.06 (0.79–1.44)	0.692
Sodium (per 1 mmol/L)	−0.12	0.89 (0.81–1.02)	0.090
B. Model 1 — clinical (intercept −6.207)			
Symptom duration (per 12 h)	1.999	7.38 (2.43–44.49)	< 0.001
Bloody stool	3.278	26.52 (2.72–905.4)	0.003
Lethargy	1.326	3.77 (0.46–36.19)	0.208
AUC 0.986 (0.943–0.996); optimism-corrected 0.975; Brier 0.055			
C. Model 2 — ultrasonographic (intercept −10.117)			
Intussusceptum length (per 10 mm)	1.849	6.35 (2.28–31.28)	< 0.001
Trapped fluid	2.765	15.87 (1.34–2,252)	0.026
Reduced or absent Doppler flow	1.888	6.61 (1.10–69.38)	0.038
AUC 0.971 (0.915–0.991); optimism-corrected 0.963; Brier 0.072			
D. Model 3 — combined (intercept −10.689)			
Symptom duration (per 12 h)	2.520	12.43 (2.90–485.9)	< 0.001
Intussusceptum length (per 10 mm)	0.724	2.06 (0.24–30.51)	0.469
Trapped fluid	4.919	136.8 (0.97 to > 10,000)	0.052
AUC 0.997 (0.969–1.000); optimism-corrected 0.994; Brier 0.019			

CIs are profile penalised-likelihood intervals; p values are from penalised likelihood-ratio tests. Optimism correction used 500 bootstrap resamples. AUC, area under the receiver operating characteristic curve; OR, odds ratio.

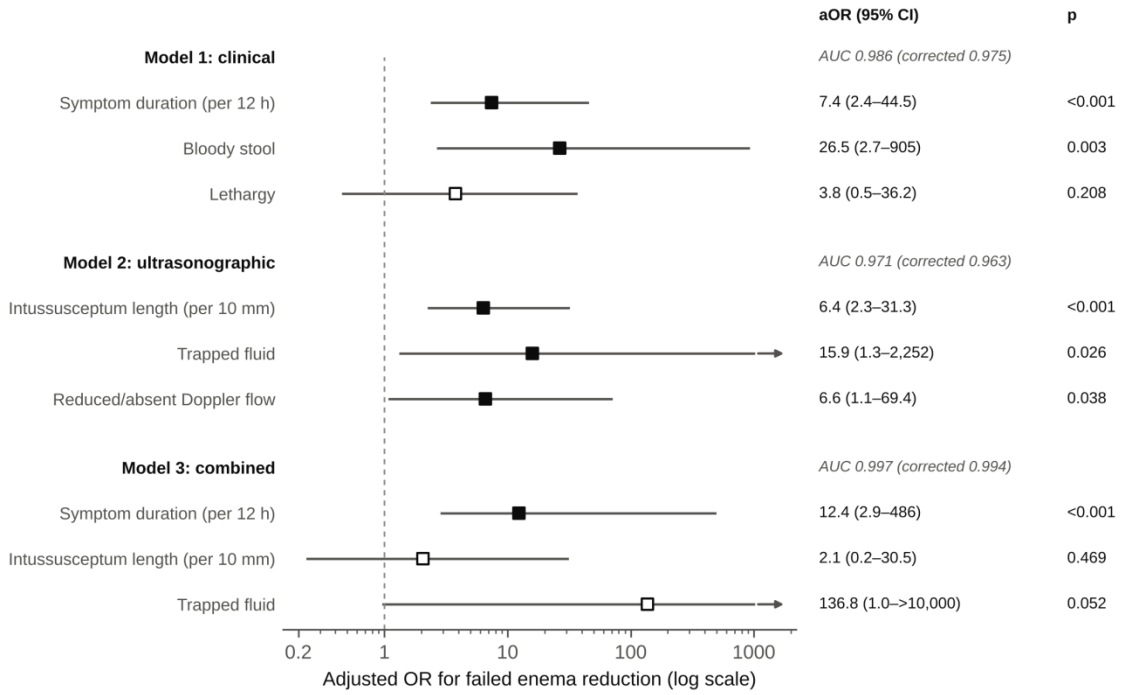


Figure 5. Adjusted odds ratios from the three pre-specified Firth logistic regression models. Apparent AUCs are shown with bootstrap optimism-corrected values in parentheses. Filled squares mark p < 0.05; arrows mark upper confidence limits beyond the plotted range.

Discrimination and a simple score

Symptom duration (AUC 0.950) and intussusceptum length (AUC 0.936) were the best single discriminators. Their Youden cut-offs were 26 h and 48 mm, each giving a sensitivity of at least 90% and a specificity of 86.7%. Lactate, diameter, wall thickness and white-cell count discriminated moderately well (AUC 0.82–0.88); CRP did so poorly (AUC 0.72). Trapped fluid was fully specific but detected only 56.7% of failures (Table 5; Figure 6).

The three models discriminated very well, and their AUCs did not differ significantly (Model 3 vs Model 1, p = 0.186; Model 3 vs Model 2, p = 0.091; Model 1 vs Model 2, p = 0.416). Bootstrap optimism was small (0.002–0.011). A score giving one point each for symptoms of 26 h or more, length of 48 mm or more and trapped fluid had an AUC of 0.983 (0.936–0.996). No child with a score of 0 failed reduction (0/23), compared with 2 of 8 with a score of 1, 14 of 15 with a score of 2 and all 14 with a score of 3 (Figure 7). A score of 2 or more identified failure with 93.3% sensitivity and 96.7% specificity.

Table 5. Discriminative performance of single predictors, the three-item score and the multivariable models

Predictor	AUC (95% CI)	Cut-off	Sensitivity, % (95% CI)	Specificity, % (95% CI)	PPV, %	NPV, %	Youden J
Symptom duration	0.950 (0.839–0.986)	≥ 26 h	93.3 (78.7–98.2)	86.7 (70.3–94.7)	87.5	92.9	0.80
Intussusceptum length	0.936 (0.851–0.974)	≥ 48 mm	90.0 (74.4–96.5)	86.7 (70.3–94.7)	87.1	89.7	0.77
Lactate	0.878 (0.760–0.942)	≥ 2.0 mmol/L	80.0 (62.7–90.5)	80.0 (62.7–90.5)	80.0	80.0	0.60
Transverse diameter	0.838 (0.711–0.916)	≥ 30.2 mm	83.3 (66.4–92.7)	73.3 (55.6–85.8)	75.8	81.5	0.57
Outer wall thickness	0.837 (0.709–0.915)	≥ 4.5 mm	86.7 (70.3–94.7)	70.0 (52.1–83.3)	74.3	84.0	0.57
White-cell count	0.816 (0.688–0.899)	≥ 11.5 × 10^9/L	90.0 (74.4–96.5)	56.7 (39.2–72.6)	67.5	85.0	0.47
Vomiting episodes per day	0.791 (0.661–0.879)	≥ 5	73.3 (55.6–85.8)	70.0 (52.1–83.3)	71.0	72.4	0.43
C-reactive protein	0.716 (0.566–0.829)	≥ 12 mg/L	83.3 (66.4–92.7)	60.0 (42.3–75.4)	67.6	78.3	0.43
Bloody stool	—	present	76.7 (59.1–	90.0 (74.4–	88.5	79.4	0.67

Journal of Kyzylorda Scholarly Review
P-ISSN:3006-0265 | E-ISSN:3007-4681
https://bulletin.ouk.kz/index.php/bulletin/index

			88.2)	96.5)			
Trapped fluid	—	present	56.7 (39.2–72.6)	100 (88.6–100)	100	69.8	0.57
Three-item score	0.983 (0.936–0.996)	≥ 1	100 (88.6–100)	76.7 (59.1–88.2)	81.1	100	0.77
		≥ 2	93.3 (78.7–98.2)	96.7 (83.3–99.4)	96.6	93.5	0.90
		3	46.7 (30.2–63.9)	100 (88.6–100)	100	65.2	0.47
Model 1 (clinical)	0.986 (0.943–0.996)	p ≥ 0.5	83.3	93.3	—	—	—
Model 2 (ultrasonographic)	0.971 (0.915–0.991)	p ≥ 0.5	86.7	90.0	—	—	—
Model 3 (combined)	0.997 (0.969–1.000)	p ≥ 0.5	100	96.7	—	—	—

Predictive values assume the 50% prevalence fixed by the case–control design and will be lower in unselected cohorts. Three-item score: one point each for symptom duration ≥ 26 h, intussusceptum length ≥ 48 mm and trapped fluid. NPV, negative predictive value; PPV, positive predictive value.

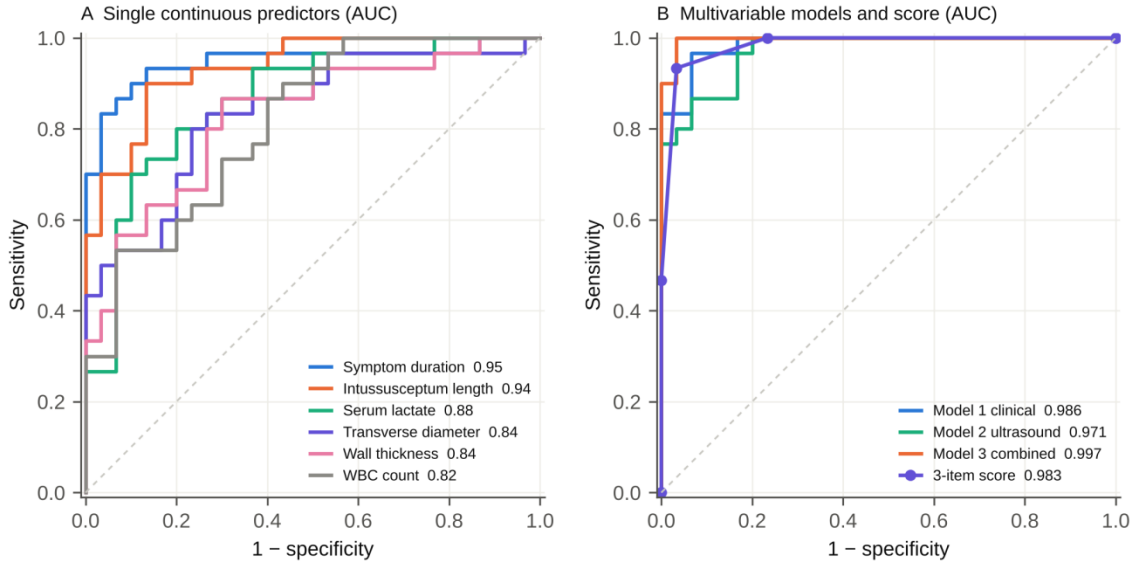


Figure 6. Receiver operating characteristic curves for (A) single continuous predictors and (B) the three multivariable models and the three-item score. AUC values are given in the legends.

Journal of Kyzylorda Scholarly Review
P-ISSN:3006-0265 | E-ISSN:3007-4681
https://bulletin.ouk.kz/index.php/bulletin/index

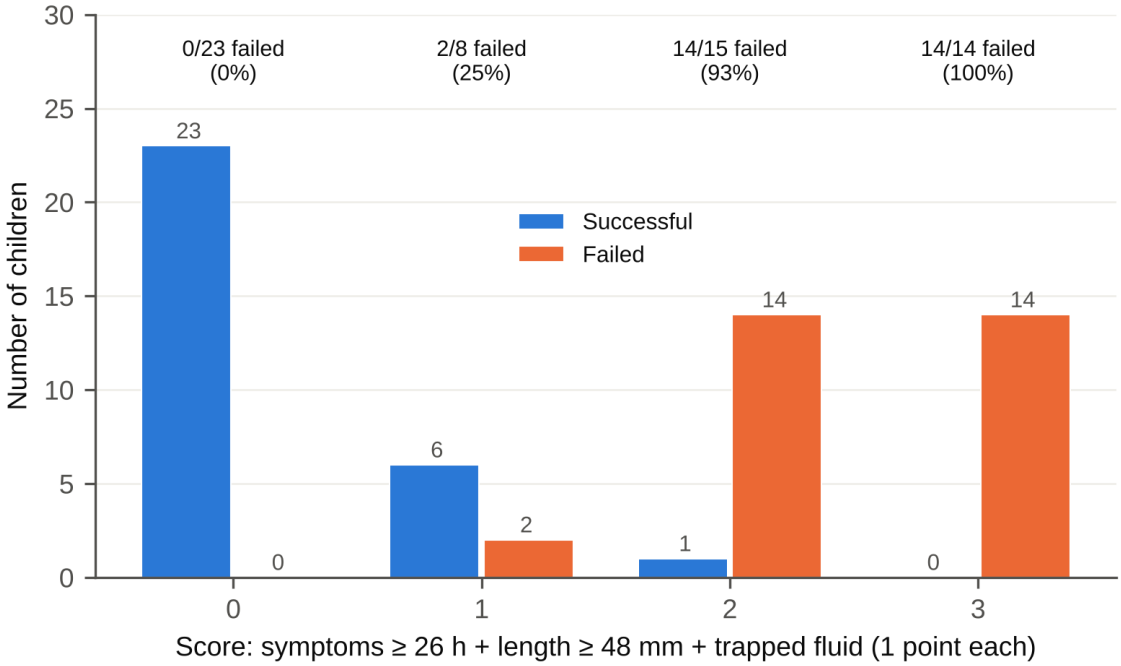


Figure 7. Distribution of the three-item score by outcome, with the proportion of failed reductions at each score. One point each was given for symptom duration ≥ 26 h, intussusceptum length ≥ 48 mm and trapped fluid.

Sensitivity analysis

Restricting the analysis to the 40 children from the two hospitals that contributed both cases and controls (20 per group) did not change the direction or significance of the main associations. Symptom duration (OR 6.7 per 12 h, 2.6–28.0; AUC 0.932), intussusceptum length (OR 10.2 per 10 mm, 3.2–89.3; AUC 0.955), trapped fluid (15/20 vs 0/20; OR 115.6, 12.2–15,638), bloody stool (OR 18.3, 4.3–100.7) and impaired Doppler flow (OR 4.0, 1.2–15.4) all remained associated with failure. In the combined model, symptom duration again remained significant (aOR 5.1; p = 0.011), with trapped fluid of borderline significance (p = 0.058).

Management and outcomes

All 30 children with failed reduction underwent an operation. Manual reduction sufficed in 24, and 6 (20.0%) needed bowel resection. Resection was required in 2 of the 5 children with absent Doppler flow, in 4 of the 17 with trapped fluid and in only 1 of the 6 with a suspected lead point. Within the failed group, symptom duration did not differ between children with and without resection (median 46.5 vs 42.5 h; p = 0.378). The failed group needed more enema attempts and longer enema sessions, and stayed in hospital longer (median 7 vs 2 days; Table 6). Postoperative ileus (5 children) and one wound infection occurred only after surgery. Overall complication rates did not differ significantly (30.0% vs 20.0%; p = 0.552). No enema-related perforation and no death were recorded. Recurrence within 30 days occurred in 1 child after operative reduction and 3 after enema reduction.

Table 6. Procedure details and outcomes

Outcome	Failed (n = 30)	Successful (n = 30)	p value
Enema attempts, median (IQR)	2 (2–3)	1 (1–2)	< 0.001[a]
One attempt, n (%)	0 (0.0)	18 (60.0)	

Outcome	Failed (n = 30)	Successful (n = 30)	p value
Two attempts, n (%)	17 (56.7)	12 (40.0)	
Three attempts, n (%)	13 (43.3)	0 (0.0)	
Total enema time, min, median (IQR)	24.5 (21.0–27.0)	14.0 (9.3–23.0)	< 0.001[a]
Operative management, n (%)	30 (100)	0 (0.0)	—
Bowel resection, n (%)	6 (20.0)	0 (0.0)	0.024[b]
Hospital stay, days, median (IQR)	7 (5.3–9)	2 (1–2)	< 0.001[a]
Any complication, n (%)	9 (30.0)	6 (20.0)	0.552[b]
Postoperative ileus	5 (16.7)	0 (0.0)	
Wound infection	1 (3.3)	0 (0.0)	
Fever	2 (6.7)	2 (6.7)	
Electrolyte imbalance	1 (3.3)	4 (13.3)	
Recurrence within 30 days, n (%)	1 (3.3)	3 (10.0)	0.612[b]

[a] Mann–Whitney U test; [b] Fisher's exact test.

Discussion

In this multicentre case–control study from southern Iraq, failed enema reduction was associated with a longer interval from symptom onset, rectal bleeding and signs of systemic compromise. It was also associated with a group of sonographic findings that point to a large, congested and poorly perfused intussusception: greater length and diameter, a thick outer wall, trapped fluid and loss of Doppler signal. Symptom duration and intussusceptum length each separated the groups with an AUC above 0.93. A three-item score built from symptom duration, length and trapped fluid sorted most children into clearly low-risk or clearly high-risk groups.

Symptom duration and clinical signs

The interval from onset to reduction was the most consistent factor in our data. It was the strongest single discriminator and the only variable that kept a significant independent effect in every model and in the sensitivity analysis. This agrees with previous work. In a meta-analysis, symptoms lasting less than 24 h roughly quadrupled the odds of successful reduction (OR 3.81) [12]. Symptoms beyond 24 h also predicted failure in a North American series [13] and in a recent German cohort (OR 4.29) [20], and a Thai prediction rule used a 48-h threshold [33]. Our optimal cut-off of 26 h lies close to the conventional 24-h mark. The biological explanation is plausible. As the intussusception persists, venous and lymphatic congestion makes the intussusceptum oedematous and less compressible, and arterial inflow eventually fails. A swollen apex becomes harder to push back through the ileocaecal valve, whatever the medium or pressure used. In our setting, late presentation probably reflects travel distances, referral through peripheral facilities and initial misdiagnosis as gastroenteritis, and is therefore partly modifiable.

Bloody stool was the clinical sign most strongly associated with failure and stayed independent after adjustment for duration. Rectal bleeding reflects mucosal sloughing from venous congestion and has been linked to failure in pooled data (OR for success 0.25) [12], in studies of sonographically guided saline reduction [18,20] and in recent risk-factor studies and prediction models [21,22,34]. Lethargy and moderate or severe dehydration were

strongly associated with failure in univariable analysis, as others have reported [13,21]. Lethargy lost its significance once duration and bleeding were taken into account. It probably marks the same advanced stage of disease rather than an independent mechanism. Fever, which was associated with failure in the meta-analysis [12], did not differ between our groups.

The laboratory findings point the same way. White-cell count and CRP were higher in the failed group, and white-cell count was one of seven variables in a recent Chinese nomogram [21]. Venous lactate showed the clearest separation (AUC 0.88; cut-off 2.0 mmol/L). A Korean emergency department study found that higher lactate was independently associated with poor outcome, defined as early recurrence or surgery (1.70 vs 1.30 mmol/L) [35]. Lactate is cheap and available at the bedside. It deserves prospective study as an adjunct to sonography, although our sample was too small to test it in a multivariable model without overfitting.

Ultrasonographic findings

The sonographic results help to explain why longer illness leads to failure. In children whose reduction failed, the intussusception was on average 18 mm longer and 7 mm wider, and its outer wall was thicker. Each 10 mm of length increased the odds of failure about ninefold. A long-axis measurement was also among the predictors of surgical intervention in a nomogram for hydrostatic reduction [21]. A long intussusception carries more mesentery into the mass, which compresses its vessels more and leaves a longer segment to be reduced. Length lost its independent effect in the combined model. We think this reflects its correlation with symptom duration ($\rho = 0.57$) rather than a lack of importance: the intussusception lengthens and swells over time.

Trapped fluid was the most specific sign. It was found in more than half of the failed reductions and in none of the successful ones. Del-Pozo and colleagues first showed that fluid inside the intussusception lowered the reduction rate from 89% to 26% and was associated with ischaemia at surgery [14]. Later work linked fluid collections of 9 mm or more to failure and to lead points or necrosis [15], and reported a success rate of only 25% for air enema when trapped fluid was present [17]. Its pooled odds ratio for success was 0.18 [12]. Our data add that trapped fluid had a specificity of 100% but a sensitivity of only 57%. Its presence should therefore change management, whereas its absence offers little reassurance.

Reduced or absent Doppler flow was independently associated with failure in the sonographic model, and all five children without any detectable flow failed reduction. This matches the original report, in which 94% of intussusceptions with a Doppler signal were reduced pneumatically, whereas the three without a signal needed resection [16]. A negative Doppler signal was also associated with unsuccessful saline enema in a Spanish series [19]. Free peritoneal fluid and small-bowel obstruction were more common after failure, in line with earlier sonographic studies and with the pooled association between ascites and failure [12,17,19]. Neither finding is specific, and small amounts of free fluid are common in uncomplicated cases.

A suspected lead point was found only in children whose reduction failed. Pathological lead points are a recognised cause of irreducibility, accounting for about a quarter of failed reductions in one large series [11,36,37]. Only one of our six children with a suspected lead point needed resection, however, and histology was not available. Sonographic suspicion of

a lead point was therefore unconfirmed in most cases, and this variable should be interpreted cautiously.

Two factors reported elsewhere could not be tested here. A left-sided or distal intussusception is a strong predictor of failure [12,13,18,19], but none of our children had a left-sided head. Age under one year has also been linked to failure [12], yet age did not differ between our groups.

Enema modality

Failure rates were almost identical after hydrostatic and pneumatic reduction. Pooled observational data and a Cochrane review of randomised trials favour air [6,7], and one Thai cohort found hydrostatic reduction to be a risk factor for failure [8]. Our study was not designed to compare techniques. Modality depended on the hospital and its equipment, and the case–control sampling does not allow valid estimates of success rates by modality. The finding should not be read as evidence of equivalence.

Clinical implications

The three-item score uses information available before the first enema, needs no calculation and showed a steep gradient of risk. No child with a score of 0 failed reduction, whereas 28 of the 29 children with a score of 2 or 3 did. We do not suggest that a high score should replace an enema attempt in a stable child, since 1 of the 15 children with a score of 2 was reduced successfully. Repeated attempts remain reasonable when clinically appropriate [5]. A high score could instead prompt early surgical consultation, as others have recommended for children at risk [38]. It could also justify transfer to a centre with paediatric surgery, a single carefully supervised attempt rather than prolonged sessions, and early theatre planning. A score of 0 supports enema reduction in a peripheral hospital with appropriate monitoring.

Strengths and limitations

The study has several strengths. It drew on four hospitals, analysed clinical, laboratory and sonographic data together, and used Firth regression, which gives finite and less biased estimates when predictors separate the outcome completely. It also corrected the AUCs for optimism and included a sensitivity analysis restricted to hospitals that contributed both groups.

The limitations are important. First, the retrospective case–control design fixed the proportion of failures at 50%. Predictive values therefore cannot be transferred to unselected patients, and the true failure rate in our region cannot be estimated. Second, comparing clearly failed with clearly successful reductions may produce spectrum bias, which can inflate discrimination. The near-perfect AUCs of the multivariable models, though corrected for optimism, almost certainly overstate their performance in practice. Third, two hospitals contributed only one group. Differences in case mix, equipment or operator experience could therefore be confounded with outcome, although the main associations persisted when these hospitals were excluded. Fourth, with 30 events, the confidence intervals were wide, particularly for trapped fluid, and models had to be kept to three variables. Fifth, ultrasonography and enema reduction were performed by different operators at four hospitals, and inter-observer agreement for the sonographic signs was not measured. Sixth, 18 of the 78 children assessed (23.1%) were excluded, and selection bias cannot be ruled out if they differed from those analysed. Seventh, lethargy and dehydration were graded clinically. Finally, operative and histological findings were not available for all cases, so we could not relate the sonographic signs to bowel viability or to confirmed lead

points. Many comparisons were made, and secondary findings should be regarded as hypothesis-generating.

A prospective multicentre cohort with consecutive enrolment, a standard reduction protocol and blinded review of sonographic images is needed to validate the score and to estimate its predictive values in the population in which it would be used.

Conclusions

In children with intussusception treated in southern Iraq, failed enema reduction was associated with symptoms lasting more than about one day, rectal bleeding, lethargy and dehydration. It was also associated with a long and wide intussusception, a thick outer wall, trapped fluid and reduced or absent Doppler flow. Symptom duration and bloody stool were the strongest independent clinical factors; intussusceptum length, trapped fluid and impaired Doppler flow were the strongest independent sonographic factors. A simple score combining symptoms of 26 h or more, a length of 48 mm or more and trapped fluid separated low-risk from high-risk children well in this sample. Children with these features should be managed with early surgical involvement and a time-limited reduction strategy. The score now needs prospective, external validation before it can guide routine care.

References

1. Jiang J, Jiang B, Parashar U, Nguyen T, Bines J, Patel MM. Childhood intussusception: a literature review. PLoS One. 2013;8(7):e68482. doi:10.1371/journal.pone.0068482
2. Edwards EA, Pigg N, Courtier J, Zapala MA, MacKenzie JD, Phelps AS. Intussusception: past, present and future. Pediatr Radiol. 2017;47(9):1101–8. doi:10.1007/s00247-017-3878-x
3. Daneman A, Navarro O. Intussusception. Part 1: a review of diagnostic approaches. Pediatr Radiol. 2003;33(2):79–85. doi:10.1007/s00247-002-0832-2
4. Applegate KE. Intussusception in children: evidence-based diagnosis and treatment. Pediatr Radiol. 2009;39 Suppl 2:S140–3.
5. Kelley-Quon LI, Arthur LG, Williams RF, Goldin AB, St Peter SD, Beres AL, et al. Management of intussusception in children: a systematic review. J Pediatr Surg. 2021;56(3):587–96. doi:10.1016/j.jpedsurg.2020.09.055
6. Gluckman S, Karpelowsky J, Webster AC, McGee RG. Management for intussusception in children. Cochrane Database Syst Rev. 2017;6(6):CD006476. doi:10.1002/14651858.CD006476.pub3
7. Sadigh G, Zou KH, Razavi SA, Khan R, Applegate KE. Meta-analysis of air versus liquid enema for intussusception reduction in children. AJR Am J Roentgenol. 2015;205(5):W542–9. doi:10.2214/AJR.14.14060
8. Khorana J, Singhavejsakul J, Ukarapol N, Laohapensang M, Siriwongmongkol J, Patumanond J. Prognostic indicators for failed nonsurgical reduction of intussusception. Ther Clin Risk Manag. 2016;12:1231–7. doi:10.2147/TCRM.S109785
9. Flaum V, Schneider A, Gomes Ferreira C, Philippe P, Sebastia Sancho C, Lacreuse I, et al. Twenty years' experience for reduction of ileocolic intussusceptions by saline enema under sonography control. J Pediatr Surg. 2016;51(1):179–82. doi:10.1016/j.jpedsurg.2015.09.022
10. Daneman A, Navarro O. Intussusception. Part 2: an update on the evolution of management. Pediatr Radiol. 2004;34(2):97–108.
11. Ntoulia A, Tharakan SJ, Reid JR, Mahboubi S. Failed intussusception reduction in children: correlation between radiologic, surgical, and pathologic findings. AJR Am J Roentgenol. 2016;207(2):424–33.
12. Kim PH, Hwang J, Yoon HM, Lee JY, Jung AY, Lee JS, et al. Predictors of failed enema

reduction in children with intussusception: a systematic review and meta-analysis. Eur Radiol. 2021;31(11):8081–97. doi:10.1007/s00330-021-07935-5
13. Fike FB, Mortellaro VE, Holcomb GW 3rd, St Peter SD. Predictors of failed enema reduction in childhood intussusception. J Pediatr Surg. 2012;47(5):925–7. doi:10.1016/j.jpedsurg.2012.01.047
14. del-Pozo G, González-Spínola J, Gómez-Ansón B, Serrano C, Miralles M, González-de-Orbe G, et al. Intussusception: trapped peritoneal fluid detected with US — relationship to reducibility and ischemia. Radiology. 1996;201(2):379–83. doi:10.1148/radiology.201.2.8888227
15. Gartner RD, Levin TL, Borenstein SH, Han BK, Blumfield E, Murphy R, et al. Interloop fluid in intussusception: what is its significance? Pediatr Radiol. 2011;41(6):727–31. doi:10.1007/s00247-010-1931-0
16. Lim HK, Bae SH, Lee KH, Seo GS, Yoon GS. Assessment of reducibility of ileocolic intussusception in children: usefulness of color Doppler sonography. Radiology. 1994;191(3):781–5. doi:10.1148/radiology.191.3.8184064
17. Britton I, Wilkinson AG. Ultrasound features of intussusception predicting outcome of air enema. Pediatr Radiol. 1999;29(9):705–10. doi:10.1007/s002470050679
18. He N, Zhang S, Ye X, Zhu X, Zhao Z, Sui X. Risk factors associated with failed sonographically guided saline hydrostatic intussusception reduction in children. J Ultrasound Med. 2014;33(9):1669–75. doi:10.7863/ultra.33.9.1669
19. Gondek AS, Riaza L, Cuadras D, Castellarnau XT, Krauel L. Ileocolic intussusception: predicting the probability of success of ultrasound guided saline enema from clinical and sonographic data. J Pediatr Surg. 2018;53(4):599–604. doi:10.1016/j.jpedsurg.2017.10.050
20. Braun Y, Fiegel HC, Rolle U, Theilen TM. Determinants of ultrasound-guided reduction failure and pathological lead points in pediatric intussusception. Pediatr Surg Int. 2026;42:91. doi:10.1007/s00383-026-06315-8
21. Zhuang Y, Wang X, Fan X, Li F, He G, Luo M, et al. Developing a nomogram for predicting surgical intervention in pediatric intussusception after hydrostatic reduction. Front Pediatr. 2023;11:1092548. doi:10.3389/fped.2023.1092548
22. Liu J, Wang Y, Jiang Z, Duan G, Mao X, Zeng D. Developing a nomogram for predicting surgical intervention in pediatric intussusception after pneumatic reduction: a multicenter study from China. Ther Clin Risk Manag. 2024;20:313–23. doi:10.2147/TCRM.S463086
23. Shuker MS, Abdulhassan AA, Sweedan BH. A study of 100 children with intussusception in Misan. Int J Sci Res Arch. 2022;6(1):167–71. doi:10.30574/ijsra.2022.6.1.0082
24. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet. 2007;370(9596):1453–7.
25. Bines JE, Kohl KS, Forster J, Zanardi LR, Davis RL, Hansen J, et al. Acute intussusception in infants and children as an adverse event following immunization: case definition and guidelines of data collection, analysis, and presentation. Vaccine. 2004;22(5–6):569–74. doi:10.1016/j.vaccine.2003.09.016
26. del-Pozo G, Albillos JC, Tejedor D, Calero R, Rasero M, de-la-Calle U, et al. Intussusception in children: current concepts in diagnosis and enema reduction. Radiographics. 1999;19(2):299–319. doi:10.1148/radiographics.19.2.g99mr14299
27. Firth D. Bias reduction of maximum likelihood estimates. Biometrika. 1993;80(1):27–38.
28. Heinze G, Schemper M. A solution to the problem of separation in logistic regression. Stat Med. 2002;21(16):2409–19. doi:10.1002/sim.1047
29. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR. A simulation study of the number of events per variable in logistic regression analysis. J Clin Epidemiol. 1996;49(12):1373–9.

30. DeLong ER, DeLong DM, Clarke-Pearson DL. Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. Biometrics. 1988;44(3):837–45.
31. Youden WJ. Index for rating diagnostic tests. Cancer. 1950;3(1):32–5.
32. Harrell FE Jr, Lee KL, Mark DB. Multivariable prognostic models: issues in developing models, evaluating assumptions and adequacy, and measuring and reducing errors. Stat Med. 1996;15(4):361–87.
33. Khorana J, Patumanond J, Ukarapol N, Laohapensang M, Visrutaratna P, Singhavejsakul J. Clinical prediction rules for failed nonoperative reduction of intussusception. Ther Clin Risk Manag. 2016;12:1411–6. doi:10.2147/TCRM.S115253
34. Xie X, Wu Y, Wang Q, Zhao Y, Xiang B. Risk factors for failure of hydrostatic reduction of intussusception in pediatric patients: a retrospective study. Medicine (Baltimore). 2019;98(1):e13826. doi:10.1097/MD.0000000000013826
35. Lee JY, Byun YH, Park JS, Lee JS, Ryu JM, Choi SJ. Lactic acid level as an outcome predictor in pediatric patients with intussusception in the emergency department. BMC Pediatr. 2020;20(1):184. doi:10.1186/s12887-020-02095-9
36. Younes A, Lee S, Lee JI, Seo JM, Jung SM. Factors associated with failure of pneumatic reduction in children with ileocolic intussusception. Children (Basel). 2021;8(2):136. doi:10.3390/children8020136
37. Navarro O, Daneman A. Intussusception. Part 3: diagnosis and management of those with an identifiable or predisposing cause and those that reduce spontaneously. Pediatr Radiol. 2004;34(4):305–12.
38. Fallon SC, Lopez ME, Zhang W, Brandt ML, Wesson DE, Lee TC, et al. Risk factors for surgery in pediatric intussusception in the era of pneumatic reduction. J Pediatr Surg. 2013;48(5):1032–6. doi:10.1016/j.jpedsurg.2013.02.021