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Predictive factors for failure of nonsurgical management of intussusception and its in-hospital recurrence in pediatric patients: a large retrospective single-center study

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Abstract

Background This study explores the effectiveness of ultrasonography (USG)-guided saline enema reduction for ileocecal intussusception. It investigates factors, ascertainable through physical examination, ultrasound, and medical history, that impact the success of the procedure and the likelihood of recurrence.

Results Conducted at a tertiary referral center, the study included 323 pediatric cases diagnosed with intussusception between 2017 and 2023. Patient data, symptoms, signs, and outcomes were collected. Hydrostatic saline enema, performed under USG guidance, served as the primary non-operative treatment. Logistic regression models assessed the impact of clinical factors on success and recurrence rates. Out of 323 patients examined for eligibility, 184 met inclusion criteria and were analyzed. Successful reduction with saline enema was achieved in 86.7%. In-hospital recurrence occurred in 17.1%, notably higher for intussusceptions extending into the rectum ($p < 0.03$). Pathologic lead point was identified in 33.3% of operated cases. The study revealed a correlation between the increasing number of symptoms ($p < 0.001$) and reduced success rates in enema reduction, with vomiting ($p < 0.02$), diarrhea ($p < 0.05$), and peritoneal fluid ($p < 0.008$) negatively affecting outcomes. Symptom duration of 1–9 h ($p < 0.001$) and 10–24 ($p < 0.01$) correlated with higher success rates, but prolonged symptom duration of > 24 ($p = 0.4$) and 48–72 ($p = 0.2$) hours did not decrease chances for successful reduction.

Conclusions Prolonged symptom duration of over 24 and 48–72 h should not be a definitive contraindication for non-operative treatment. Cumulation of symptoms typical for intussusception might reduce the chances of success. These findings contribute valuable insights into optimizing non-operative strategies for managing pediatric intussusception.

Keywords Pediatric surgery, Abdominal emergency, Non-invasive treatment, Intussusception, Abdominal pain

Background

Intussusception is the most common abdominal emergency in children under the age of 2 years old with an incidence rate between 1 and 4 per 2000 children [1–3]. Timely treatment is crucial as it can lead to lumen obstruction and vascular compromise if left untreated [4]. Manifestations are abdominal pain, a palpable abdominal mass, emesis, and passage of stools mixed with blood

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and mucus, known as "red currant jelly stools". Nevertheless, patients may present with nonspecific manifestations [3, 5]. The prevailing site is the ileocolic region [6, 7]. Approximately 90% of intussusceptions are idiopathic; however, lymphoid tissue hyperplasia can serve as a leading point [1, 7, 8].

Intussusception is diagnosed when a so-called donut or target sign is seen with ultrasonography. This diagnostic method is highly accurate with a specificity and sensitivity of almost 100% [1, 9]. The treatment of choice is nonoperative, with surgical intervention reserved for failure in achieving reduction. There are different techniques for enema reduction, the most frequent are normal saline and air enema [1–9]. Various reports diverge on the best reduction approach.

The primary objective of this study was to evaluate the results of our experience in USG-guided saline enema reduction of intussusceptions and investigate a possible influence of clinical presentation, location, and symptom duration on the success of non-operative treatment. The secondary objective of our study was to assess these factor's influence on the recurrence of intussusception.

Methods

The medical records of 323 children admitted to the University Children's Hospital of Cracow, Department of Pediatric Surgery, between January 2017 and July 2023 with the diagnosis of ileocecal intussusception were retrieved from the electronic health records using ICD-10 code K56.1. The study was conducted at the tertiary referral level with 33,000 annual ER visits.

Data regarding the patient's characteristics (sex, age (months), body weight (kilograms), intestinal pathology), symptoms (vomiting, presence of blood in stool, presence of mucus in stool, loose consistency of stool, diarrhea, constipation, coexisting infection at the time of the admission and duration of symptoms), signs (fever, presence of peritoneal signs), and treatment method with outcomes was collected. Positive imagining records ("target sign") were analyzed for the presence of enlarged lymph nodes, fluid in the peritoneal cavity, and the extent of the intussusceptum. Three researchers worked on data collection and reviewed each other's work to eliminate potential source of bias.

Patients aged 18 years or older at the time of admission, individuals primarily diagnosed with ileo-ileal intussusception, those having a diagnosis corrected to ileo-ileal intussusception, or those lacking sonographic confirmation of the diagnosis were omitted from the analysis. Additionally, children with incomplete medical records lacking intervention details and those who received an enema in the emergency room were also excluded from the study.

Patients with a pre-interventional finding or a suspicion of conditions such as Meckel's diverticulum, intestinal malrotation, intestinal duplication, peritonitis, or perforation were primarily qualified for a surgical intervention. Other children were regarded as eligible for a nonsurgical reduction.

During hydrostatic reduction, patients were analgosedated, an 18- to 24-French Foley catheter was inserted into the rectum, a balloon was inflated, and the enema fluid height was maintained at around 100 cm. The enema fluid was saline and kept at a body temperature. The whole procedure was performed under USG guidance. Around the time of the procedure, patients were administered antibiotics (amoxicillin and clavulanic acid 30 mg/kg, intravenous). The standard for the number of unsuccessful enema attempts before deciding to operate was 3.

The success of reduction using hydrostatic saline enema was determined by the disappearance of intussusception under ultrasound guidance with reflux of saline into the ileum. Surgical intervention was carried out, when after 3 failed enema attempts, the disappearance of intussusception was not observed upon radiography. Enema reductions followed by an operative treatment were regarded as failure. After an enema procedure, the outcome was recorded as binary data: 1 for success or 0 for failure. Patients were hospitalized and monitored for 2 to 3 days post-procedure. Therefore, in-hospital recurrent intussusceptions were defined as recurrence after a successful hydrostatic saline enema reduction or surgical reduction within 3 days post-procedure.

The reduction was deemed spontaneous when upon second ultrasonography, before the beginning of the intervention in the operating room no "target sign" was visible. Patients were hospitalized till the next day, for a period of a minimum of 12 h, and observed for a potential recurrence.

Symptoms present upon clinical evaluation (medical history, physical examination, ultrasonography report) performed in the emergency room (ER) were analyzed and recorded in binary format: 1 indicating the presence of a symptom and 0 indicating its absence. The attainable score for an individual patient ranged from 0 (minimum) to 11 (maximum) points.

All the collected data were arranged into arrays for analysis. Each array represented a symptom, and the length of an array corresponded to the number of patients in the study.

A logistic regression model was fitted to the data to ascertain the effect of individual symptoms on the success rate of enemas and recurrence of intussusception. The results included coefficient estimates, standard errors, and significance levels. 95% confidence intervals

were also calculated to determine the reliability of the coefficient estimates. Moreover, relationships between certain factors were investigated, using the chi-square test and Wilcoxon rank-sum test. *P* value less than 0.05 was considered significant. The protocol was approved by the Institutional Review Board.

Results

Out of 323 patients potentially eligible for the study and examined for eligibility, 184 who met inclusion criteria were confirmed eligible, included in the study, and analyzed.

A total of 220 episodes of intussusception were identified among 184 patients admitted to the Department of Pediatric Surgery between January 2017 and July 2023. There were 117 (63.6%) male patients and 67 (36.4%) female patients. The age distribution of study subjects was abnormal, ranging from 3 to 122 months (median 29 months). Body weight distribution in our series was abnormal, ranging from 5.3 to 48.8 kg (median 13.65 kg). Table 1 details the patient's characteristics influence on enema's outcome.

Out of 184 admissions, 158 (85.8%) underwent enema reduction as a primary treatment, 7 (3.8%) underwent a primary surgery without an attempted enema, and 19 (10.4%) had a spontaneous relief of a primary intussusception while being hospitalized and did not require any intervention. Out of those only 1 patient had a recurrence followed by another spontaneous relief. There was an incidence of spontaneous relief after a recurrence in 4 patients. Total number of patients with spontaneous relief was 23 (12.5%).

There were 198 enemas total performed in 158 patients. One hundred thirty-seven patients had successful reduction with saline enema while in 21 patients it failed, and these had to be operated upon; the success rate achieved with the procedure was 86.7%. Among these patients, 27 had a recurrence within 3 days after enema (Fig. 1).

Pathology as a leading point of intussusception was found in 11 out of 33 (33.3%) operated patients, with Meckel's diverticulum identified as the most common. As detailed in Table 2, 100% of patients with pathologic lead points had to be operated.

A total of 33 patients underwent surgical treatment, with 21 requiring operative intervention after repeated unsuccessful hydrostatic saline enema. Intraoperatively, it was revealed that 7 children had Meckel's diverticulum, 2 patients with Meckel's diverticulum had necrotically altered vermiform appendix, 1 patient had intestinal malrotation, and 2 patients displayed symptoms of intestinal bleeding. In 7 patients, surgery was chosen as a primary treatment option due to the preoperative finding of

Table 1 Correlation between patients' characteristics, number of symptoms, presence of particular symptoms, signs and findings, and success of hydrostatic saline enema reduction

Patients' characteristics	**Count (*N* = 158)**	**Mean ± SD**	***p*-value**	
Age (months)	N/A	34 ± 29.95	0.3	
Weight (kg)	N/A	14.28 ± 4.82	0.1	
Male	102	N/A	0.2	
Female	56	N/A		
Number of symptoms	**Count (*N* = 354) (range 0–11)**	**Log odds of success**	**95% CI**	***p*-value**
Increasing number of symptoms	354	−0.55	−0.9 to −0.3	< 0.0003
Symptoms	**Count (*N* = 354)**	**Log odds of success**	**95% CI**	***p*-value**
Infection	34	1.25	−0.9 to 3.3	0.2
Blood in stool	21	−0.87	−2.5 to 0.8	0.3
Diarrhea	17	−1.97	−3.9 to −0.1	**< 0.05**
Mucus in stool	6	−0.07	−2.4 to 2.3	0.9
Loose stool	20	0.35	−2.1 to 2.8	0.8
Constipation	25	Insufficient data	Insufficient data	Insufficient data
Fever	34	1.7	−0.7 to 4.1	0.2
Peritoneal signs	5	−1.46	−4.7 to 1.8	0.4
Emesis	77	−2.9	−5.3 to −0.5	< 0.02
USG: enlarged lymph nodes	64	−0.14	−1.7 to 1.5	0.9
USG: Fluid in peritoneal cavity	51	−2.06	−3.6 to −0.6	< 0.008

Symptom count means the sum of the clinical manifestations and radiographic findings. The minimum attainable sum was 0 and the maximum was 11. Infection relates to upper respiratory tract infections. The term "peritoneal signs" is to describe a rigid and painful abdomen upon palpation, guarding of the abdomen, or rebound tenderness

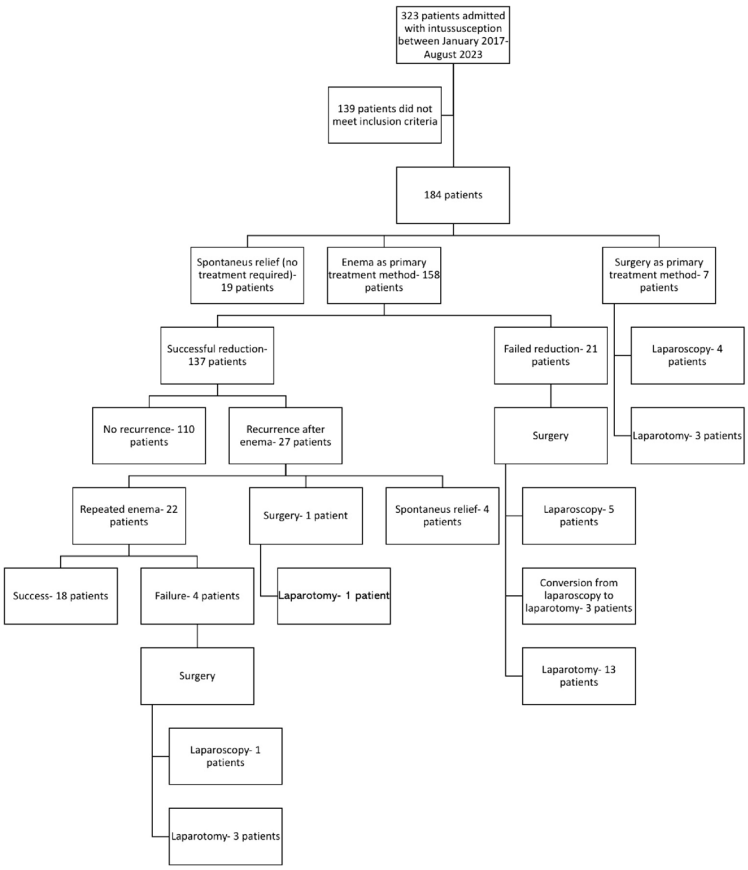

Fig. 1 Diagram presenting treatment method and its outcomes in patients admitted with intussusception. All patients, except for those with substantial contraindications (PLPs, peritonitis, or due to a subjective decision of a surgeon on duty and an individual approach to each patient), were primarily deemed eligible for enema. Some patients had a spontaneous reduction, noticed upon pre-treatment ultrasound

Table 2 Pathologies identified in 11 operated patients

Pathology	Number of patients	Percentage (%) of all 33 operated patients
Meckel's diverticulum	8	24.2
Peutz-Jeghers syndrome	1	3.03
Intestinal duplication	1	3.03
Malrotation	1	3.03
Total	11	33.3

Meckle's diverticulum and a suspected acute appendicitis (1 patient), intestinal duplication (1 patient), upper gastrointestinal tract bleeding (2 patients), Peutz-Jeghers syndrome (1 patient), presence of neuroblastoma in retroperitoneal space (1 patient), and long duration of symptoms of over 72 h (1 patient). The last-mentioned patient with a prolonged duration of symptoms had distended intestinal loops, thickened intestinal walls, and swelling of Bauchine's valve, which resulted in obstruction, and there was a necessity for provisional parenteral nutrition. He was released home after 6 days of hospitalization.

The most prevalent extent of intussusception was the right lower quadrant, in a close proximity to the ileocecal valve. Positive log odds of success value and p-value < 0.01 indicate a high chance of success of enema reduction for this location. In 16 (8.5%) patients, the extent of intussusception reached the transverse colon, and in 4 (2.1%) patients, it extended into the rectum. The negative log odds of success and a p-value < 0.01 show that for those locations there can be a lower chance of success with enema reduction. Table 3 details the likelihood of success based on the extent or type of intussusception.

The most common presenting symptom or sign in children with intussusception was emesis, occurring in 83 (45.4%) patients. Table 1 presents the influence of the number of symptoms revealed upon examination on the success as well as the possible correlation between the presence of individual symptoms, signs, and findings and reaching the goal with this method of reduction. The negative log odds of success and a p-value < 0.001 indicate

Table 3 Likelihood of success based on the extent of intussusception

Extent of intussusception	Count ($N=162$)	Log odds of success	95% CI	*P*-value
Right lower quadrant, ileocecal valve	92	1.44	0.5 to 2.5	**< 0.01**
Ascending colon	18	−0.73	−1.9 to −0.6	0.2
Hepatic flexure	27	−0.15	−1.3 to 1.2	0.8
Transverse colon	14	−1.86	−3.1 to −0.6	**< 0.005**
Splenic flexure	3	−1.22	−3.6 to 1.9	0.3
Descending colon	4	Insufficient data	Insufficient data	Insufficient data
Rectum	4	−1.96	−4.1 to −0.2	**< 0.01**

Table 4 The relation between duration of symptoms and odds for success of hydrostatic saline enema reduction

Duration of symptoms	Count ($N=158$)	Log odds of success	95% CI	*P*-value
1–9 h	67	2.15	0.9 to 3.5	**< 0.001**
10–24 h	49	1.93	0.6 to 3.5	**< 0.008**
25–48 h	14	0.71	−0.7 to 2.4	0.4
48–72 h	28	−1.61	−4.6 to 0.3	0.2

Table 5 Relationship between coexisting upper respiratory tract infection and increasing number of symptoms in children with intussusception

Group	Average number of symptoms	Test (Wilcoxon rank-sum test)	*P*-value
Infection	2.64	5.66	1.49×10^{-8}
No infection	1.23		

that with an increasing number of symptoms, signs, and findings, the chance for a successful reduction with hydrostatic saline enema decreases. Regarding individual findings, the presence of diarrhea, vomiting, and fluid in the peritoneal cavity revealed upon USG decreased chances of successful reduction using a hydrostatic saline enema.

Most children (122 (71.3%)) came to the hospital within 24 h of symptom onset. The relation between the duration of symptoms and the odds of success of hydrostatic saline enema reduction can be found in Table 4. There were successful enema reductions in patients with symptoms lasting longer than 24 and 48 h. For the symptom duration between 24 and 48 h, 9 out of 14 (64.3%) admitted patients were successfully treated using this method and for the duration of over 48 h—15 out of 28 patients (53.5%). Prolonged symptom duration of up to 72 h was statistically insignificant for the enema outcome.

The collected data was examined to assess the presence of correlations among specific influential factors. Although the relationship between the presence of infection and enlargement of coeliac lymph nodes was found to be statistically insignificant (p-value > 0.05), the correlation was found between having an infection and an increased number of clinical manifestations (p-value < 1.5×10^{-8}; Table 5). However, it is difficult to determine whether symptoms stemmed from an infection or if a coexisting infection rendered the child more susceptible to experiencing intussusception with a more severe clinical presentation. Relationships between the duration of symptoms and increasing extent of intussusception, presence of PLP, and peritoneal fluid as well as between the presence of PLP and the number of clinical manifestations were not found ($p > 0.05$). There was a statistically significant association between a prolonged duration of symptoms and the presence of fluid in the peritoneal cavity (p-value < 0.02; Table 6).

There were 37 episodes of intussusception recurrence in 27 children. This study fails to prove whether the individual symptoms can significantly influence the incidence of recurrence of intussusception after a successful reduction. Intussusceptions that extended into the rectum had a higher chance of recurrence. On average, there was a 50% chance of intussusception recurrence with the increasing number of symptoms. Duration of symptoms of up to 48 h was statistically insignificant for the chances of recurrence. For a duration longer than 48 h, data gathered was insufficient for statistical analysis. Results are shown in Table 7.

There were on average 1.25 enemas per one patient. Table 8 presents the influence of collected factors on the need to repeat an attempt. Although a maximum of three attempts before conversion to surgery is a standard in the center where the study was conducted, one patient had four attempts before surgical intervention, due to a subjective decision of a surgeon on duty. The positive log odds of repeats and p value < 0.03 indicate that the location in the right lower quadrant was posing a risk for the need for repetitions. Not only with an increasing number of symptoms (log odds of repeats > 0 and p value < 0.04),

Table 6 Relationship between the prolonging of the duration of symptoms and the presence of fluid in the peritoneal cavity

Duration	Fluid in the peritoneal cavity: absent	Fluid in the peritoneal cavity: present	Expected fluid: absent	Expected fluid: present
1–9 h	57	21	51.24	26.76
9–24 h	27	17	28.91	15.09
24–48 h	14	3	11.17	5.83
> 48 h	15	18	21.68	11.32
Chi-square test *p*-value = 0.0159				

Table 7 Influence of location of intussusception or its type, duration of symptoms, particular and sum of a number of symptoms, signs and findings, and particularly on the incidence of recurrence of intussusception after successful reduction

Location of intussusception	**Count (*N* = 162)**	**Log odds of recurrence**	**95% CI**	***P*-value**
Right lower quadrant, ileocecal valve	92	−0.65	−1.5 to 0.1	0.1
Ascending colon	18	−0.25	−1.8 to 0.9	0.7
Hepatic flexure	27	0.42	−0.6 to 1.4	0.3
Transverse colon	14	1.03	−0.2 to 2.2	0.1
Splenic flexure	3	0.71	−2.4 to 3.1	0.6
Descending colon	4	Insufficient Data	Insufficient Data	Insufficient Data
Rectum	4	2.58	0.5 to 5.6	**< 0.03**
Duration of Symptoms	**Count (*N* = 158)**	**Log odds of recurrence**	**95% confidence interval**	***P*-value**
1–9 h	67	−0.94	−1.9 to 0.1	0.07
9–24 h	49	−0.64	−1.7 to 0.5	0.3
24–48 h	14	−0.55	−2.2 to 0.9	0.5
Above 48 h	28	N/A	N/A	N/A
Number of symptoms	**Count (*N* = 354) (range 0–11)**	**Log odds of recurrence**	**95% confidence interval**	***P*-value**
Number of symptoms	354	0.23	−0.01 to 0.5	0.06
Symptoms	**Count (*N* = 354)**	**Log odds of recurrence**	**95% CI**	***P*-value**
Infection	34	0.6	−0.4 to 1.6	0.2
Blood in stool	21	1.07	−0.3 to 2.4	0.1
Diarrhea	17	0.24	−1.3 to 1.8	0.8
Mucus in stool	6	0.51	−1.6 to 2.7	0.6
Loose stool	20	−0.94	−2.7 to 0.8	0.3
Constipation	25	0.19	−0.9 to 1.3	0.8
Fever	34	−0.43	−1.6 to 0.7	0.5
Peritoneal signs	5	1.23	−0.8 to 3.2	0.2
Emesis	77	−0.18	−1.1 to 0.8	0.7
USG: enlarged lymph nodes	64	−0.23	−1.1 to 0.7	0.6
USG: Fluid in peritoneal cavity	51	0.79	−0.1 to 1.7	0.1

but also with the presence of fluid in the peritoneal cavity (log odds of repeats > 0 and p value < 0.05) was there a higher possibility of more attempts.

Discussion

Hydrostatic saline enema with USG guidance proves to be an effective reduction method, achieving the desired outcome even in cases with unfavorable clinical manifestations. Nevertheless, the likelihood of success shows a slight decline when dealing with an increased number of symptoms, signs, or findings and greater intussusception extent into the caecum. Except for the location of intussusception, none of the measured variables have a significant impact on the likelihood of recurrence within 3 days following a successful procedure. Overall, recurrences were an uncommon finding.

The oldest non-operative method for reducing intussusception, once considered the "golden standard", is a

Table 8 Influence of certain symptoms, increasing number of them, duration of symptoms, and location of intussusception on the need for more than one try for successful reduction with hydrostatic saline enema

Location of intussusception	**Count (*N* = 162)**	**Log odds of repeats**	**95% CI**	***P*-value**
Right lower quadrant, ileocecal valve	92	−0.94	−1.8 to −0.11	***p* < 0.03**
Ascending colon	18	0.84	−0.36 to 1.91	0.14
Hepatic flexure	27	0.76	−0.26 to 1.71	0.12
Transverse colon	14	0.33	−1.2 to 1.55	0.63
Splenic flexure	3	0.68	−2.35 to 2.78	0.56
Descending colon	4	Insufficient Data	Insufficient Data	Insufficient Data
Rectum	4	1.83	−0.33 to 3.98	0.075
Duration of symptoms	**Count (*N* = 158)**	**Log odds of repeats**	**95% CI**	***P*-value**
1–9 h	67	0.6	−0.64 to 2.13	0.38
9–24 h	49	0.94	−0.36 to 2.52	0.18
24–48 h	14	0.76	−1.03 to 2.56	0.76
Above 48 Hours	28	N/A	N/A	N/A
Number of symptoms	**Count (*N* = 354) (range 0–11)**	**Log odds of repeats**	**95% CI**	***P*-value**
Increasing number of symptoms	354	0.26	0.02 to 0.48	**< 0.04**
Symptoms	**Count (*N* = 354)**	**Log odds of repeats**	**95% CI**	***P*-value**
Infection	34	0.29	−7.29 to 1.31	0.57
Blood in stool	21	0.16	−1.19 to 1.51	0.81
Diarrhea	17	0.77	−7.70 to 2.3	0.33
Mucus in stool	6	−1.33	−3.77 to 1.11	0.28
Loose stool	20	0.29	−1.15 to 1.72	0.7
Constipation	25	0.81	−2.53 to 1.88	0.13
Fever	34	−0.28	−1.44 to 0.89	0.65
Peritoneal signs	5	−14.5	−1.91 to 1879.5	0.99
Emesis	77	−0.16	−1.13 to 0.8	0.74
USG: enlarged lymph nodes	64	0.77	−1.16 to 1.66	0.09
USG: Fluid in peritoneal cavity	51	0.95	1.86 to 4.32	**< 0.05**

hydrostatic reduction with barium under fluoroscopic monitoring. Guo et al. [10] investigated the success rate of this method in a study conducted in the People's Republic of China in 1986, which included 6296 cases collected over a 13-year period. Their findings estimated a 95% likelihood of achieving the desired outcome with this approach. In modern practice, it is being replaced by pneumatic or hydrostatic saline enema due to concerns about limiting radiation exposure, potential complications like chemical peritonitis, risk of infection, and adhesions when perforation occurs [7, 11].

The effectiveness of the method described in this study—reducing intussusception using warm saline enema guided by real-time sonography—was initially documented by Kim et al. [12] in 1982, with successful outcomes observed in two patients.

The results of the present study reflect an overall success rate of 86.7% for this method. Studies of a similar sample size such as those conducted by Flaum et al. [13] report a success rate of 83% and by Miguel et al. [14] of 85.8%. In our series, the overall success rate aligns closely with published findings, irrespective of the study group count, ranging from 76.8% [8] to 95.5% [15].

Our study highlights the significant influence of intussusception's location on the success of non-operative treatment. We observed a relatively lower success rate for intussusceptions located in the transverse colon and rectum, contrasted by a notably high success rate for those situated in close proximity to the ileocecal valve. Flaum et al. [13] found the highest success rate for the location of ascending colon (94%), transverse colon (88%), and ileocecal region (84%), while the lowest success rates were noted for occurrences in the left colon (35%). Our findings diverged from theirs concerning success rates in the transverse colon region. Fike et al. [8] in the study solely concerning predictors of failed enema reduction also noticed a correlation between the location of intussusception and a failure of hydrostatic saline enema reduction, with the lowest failure rate for the right colon and the highest in the rectosigmoid and descending colon. Our data also supports the rather intuitive notion that the more distal intussusception is less likely to be reduced

with enema; however, we had insufficient data to analyze incidents occurring in the descending colon.

This study concerns clinical manifestations observed in patients with intussusception. Our study group was quite heterogeneous regarding signs and symptoms. Emesis was found to be the most prevalent symptom, present in 42% of patients. Studies by Talabi et al. [6] and Kaiser et al. [16] also revealed vomiting to be the most common symptom, with the presence of nearly 100%.

Predicting which patients are prone to unsuccessful enema reduction holds clinical significance as it can assist healthcare providers in pinpointing those less likely to derive benefit from a subsequent enema reduction attempt. This study's findings have shown that the presence of free fluid in the peritoneal cavity, emesis, and diarrhea can be associated with failure. Potential correlation between the need for surgical treatment and clinical manifestations has been previously studied. In the study published by Flaum et al. [13], clinical symptoms were not associated with the reduction success; however, Fike et al. [8] and Peyvasteh et al. [17] recognized currant jelly stool and the presence of free peritoneal fluid as failure factors in the non-surgical treatment.

Several studies [1, 8, 17] have observed a decrease in the effectiveness of non-invasive procedures when the duration of symptoms exceeds 24 h. We did not obtain analogous results, as in our case results were statistically insignificant. This might indicate that children with prolonged symptoms should not be denied non-operative treatment solely based on this factor.

Our study investigated the likelihood of intussusception recurrence. We had a total of 37 episodes of recurrences in 27 (17.1%) patients. This recurrence rate is higher when compared to studies published by Delgado-Miguel et al. [14], Flaum et al. [13], and Sun et al. [18], in which recurrence rates ranged from 7.5 to 8%. These studies investigated cases of both late and early recurrences with intervals ranging from 1 day to 21 months post-attempted reduction. Our analysis looked into early recurrences with varying time spans from 1 to 3 days. A study by Karakus et al. [19], which inquired into early recurrences, up to 48 h, obtained a rate of 15.7%, which is similar to ours. Hence, we believe that early recurrences identified following hydrostatic reduction of intussusception under US guidance may likely represent insufficient or "false-positive" reductions. It is worth noting that US-guided intussusception reduction has demonstrated a 16% rate of false positives and a 14% rate of false negatives [20].

Our research examined potential predictive factors for the recurrence of pediatric intussusception. We found that as the number of symptoms increased, there was, on average, a 50% likelihood of recurrence. Recurrence was more common in our patients who had the primary location of intussusception in the rectum. Our analysis did not discern a statistically significant correlation between the occurrence of a specific sign, symptom, or ultrasonography (USG) finding and the likelihood of recurrence. In the study conducted by Xie et al. [21] to evaluate risk factors for the recurrence of intussusception in pediatric patients, duration of symptoms > 48 h, rectal bleeding, and location of mass on the left side were identified as significant. Although in our study duration of symptoms ranging from 1 to 48 h did not increase the risk of recurrence, the data required for analysis of a period longer than 48 h was insufficient.

The incidence of pathological lead point (PLP) in all children in our study group was 6.01%. The most common PLP was Meckel's diverticulum. All of the patients with PLP had unsuccessful reduction with enema. In 2016, Ntoulia et al. [4] investigated predictors of failed contrast enema, revealing that PLP was a reason behind failure in 25% of patients. They also noted that although screening ultrasound can decrease the number of unnecessary enema reduction attempts, diagnosing classic pathologic lead points such as Burkitt lymphoma and Meckel diverticulum may be difficult with the use of ultrasound [4]. In our study, four patients underwent surgery as a primary treatment due to the presence of PLP, which was revealed using different screening methods than ultrasound-computed tomography.

Ultrasound-guided hydrostatic saline enema reduction method offers several advantages over alternative methods, such as intracolonic pressure remaining stable throughout the procedure, when compared to the pneumatic enema. In contrast to pneumatic reduction, there is no risk of tension pneumoperitoneum—a life-threatening complication, where abdominal pressure instantly increases, potentially causing for example compression of the inferior vena cava [22]. Even in the rare event of perforation, there is a minimal likelihood of chemical peritonitis, a risk often associated with the use of barium. Importantly, this method eliminates the hazard of radiation exposure, prioritizing patient safety. Additionally, the ultrasound modality allows for the detection of potential lead points for intussusception, such as Meckel's diverticulum or duplications, aiding in a more comprehensive evaluation and treatment [11].

One significant drawback associated with this method is the requirement for an accessible sonologist who is proficient in utilizing this method for enema guidance [15].

The study has several limitations that need to be considered. Firstly, it is a unicentric study, potentially limiting the generalizability of the findings to a broader population. Additionally, the study's retrospective design

introduces inherent limitations, as it relies on historical data and may not capture all relevant variables or control for potential confounding factors. Therefore, while this study provides valuable insights, these limitations stemming from its unicentric nature and retrospective design should be taken into account when interpreting the results.

Conclusion

We conclude that the hydrostatic saline enema reduction of intussusception under the guidance of ultrasound is both effective and safe, making it the preferred initial treatment for appropriate patients. However, certain symptoms and their cumulation were correlating with non-surgical reduction failure; the achieved success rate was very high. While the presence of factors like diarrhea, fluid in the peritoneal cavity, and emesis should not outright prohibit the use of non-invasive methods, it is important to recognize that they increase the risk of treatment failure. Surgeons should be prepared for the possibility of needing to convert to surgery in such cases. As long as complications such as perforation, peritonitis, or the presence of pathologic lead points are ruled out, the duration of symptoms for over 24 h should not discourage pediatric surgeons from attempting the reduction; however, a higher risk for failure should be recognized. Patients presenting with intussusception extending to the rectum upon admission require closer observation due to their increased risk of an early in-hospital recurrence.

Our study sheds light on the impact of clinical manifestations that can be easily obtained upon the very first minutes of an emergency room visit and provides valuable insight for informed treatment decisions. We suggest that an optimal strategy for a nonsurgical approach would be a primary exclusion of the presence of pathologic lead points such as Meckel's diverticulum and peritonitis, using ultrasonography and physical examination. Secondly, if the patient's medical history and assessment of clinical manifestations reveal a significant number of symptoms mentioned in our study that require careful attention, having an experienced pediatric surgeon on hand who can perform such surgery is advisable. We recommend refraining from automatically deciding that surgery is necessary solely based on symptoms persisting for over 24 h. We also propose limiting unsuccessful enema attempts to three, which is a standard for this procedure in our center, because it might indicate an underlying pathology or a more significant issue. For patients with primary intussusception extending to the rectum, we advocate for more frequent post-interventional ultrasonography and monitoring for signs such as crying and screaming, since they are at higher risk of early in-hospital recurrence.

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Authors' contributions
MKCh, MP, and FP conceived and designed the analysis; MKCh, MP, and ZŁ collected the data; FP performed the statistical analysis; MKCh wrote the original draft; WG reviewed and edited the writing; MG and WG were responsible for validation, project administration, and supervision.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study has been approved by the Committee of Ethics in Scientific Research of Jagiellonian University- Collegium Medicum. Approval number 118.6120.97.2023, date of issue 25.10.2023.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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