Pediatric Surgery International (2025) 41:231
https://doi.org/10.1007/s00383-025-06138-z

ORIGINAL ARTICLE

Protocolized management of intussusception in children: optimizing pneumatic reduction outcomes

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Accepted: 16 July 2025 / Published online: 25 July 2025
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Abstract

Background Intussusception is the most common cause of intestinal obstruction in children, requiring timely management to avoid serious complications. Pneumatic reduction is widely accepted as the first-line non-operative treatment, though its success may be influenced by factors such as prolonged symptom duration, intussusception type, and advanced intussusceptum location. The role of adjunct therapies, including corticosteroids, remains uncertain. This study aimed to evaluate the outcomes of a standardized modified pneumatic reduction (MPR) protocol implemented at a single national pediatric center.

Materials and methods A retrospective review was conducted of 92 admissions involving 79 patients treated between May 2016 and October 2024. The MPR protocol employed a manual sphygmomanometer-based system with incremental pressure adjustments and selective intravenous hydrocortisone for specific indications. Standardized documentation and follow-up protocols were applied.

Results MPR achieved a 99% success rate, with complications limited to one case of pneumoperitoneum (1%) and self-limiting mild desaturation in 6% of cases. Early and delayed recurrence rates were 16 and 10%, respectively. Factors traditionally considered limiting did not preclude successful reduction. In the subgroup of failed attempts or recurrent cases, hydrocortisone use was associated with an increase in the proportion of 'easy' reductions from 47 to 83% ($p = 0.038$), suggesting a potential benefit warranting further investigation.

Conclusion A structured, protocolized MPR approach resulted in high success and low complication rates, even in challenging scenarios. These findings support the value of standardized non-operative management and suggest a possible targeted role for hydrocortisone in selected cases.

Keywords Intussusception · Pneumatic reduction · Hydrocortisone · Air enema reduction · Resource-limited settings

Introduction

Intussusception is the most common cause of intestinal obstruction in young children, presenting as an acute abdominal emergency. If left untreated, it can lead to severe complications such as bowel necrosis, perforation, and sepsis. Early diagnosis and effective management are crucial to prevent morbidity and mortality. While the traditional treatment options include surgical intervention, non-operative techniques such as pneumatic or hydrostatic reduction have become the preferred first-line approaches due to their high success rates and lower complication profiles [1].

Pneumatic reduction, introduced in the late nineteenth century and refined over subsequent decades, is now widely adopted due to its superior efficacy and safety compared to hydrostatic reduction. Success rates for pneumatic reduction generally range from 80 to 90% in most centers [1–5], with rates exceeding 95% reported rarely [6, 7]. Variability in outcomes has been linked to differences in technique, patient factors, adherence to structured protocols, and operator expertise [5]. Factors such as prolonged symptom duration, ileo-ileo-colic intussusception, and advanced location of the intussusceptum have traditionally been considered predictors of failure, often discouraging attempts of non-operative management [8–11].

Complications of pneumatic reduction, including recurrence, pneumoperitoneum, and sedation-related events, are

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well-documented but rare with standardized pneumatic reduction protocols [8–10]. Recurrence, occurring in 8–18% of cases, has been linked to younger age and transient lead points, though the literature remains inconclusive [12–17]. Pneumoperitoneum, a less frequent but significant complication, occurs in < 2% of cases, usually due to bowel perforation during reduction [10, 14]. These challenges highlight the importance of refining management protocols to optimize outcomes while minimizing complications.

In recent years, corticosteroids such as hydrocortisone have been explored as adjuncts to facilitate reduction by reducing bowel edema and inflammation. However, their routine use remains debated, with some studies suggesting benefits in selected cases while others find insufficient evidence to justify their widespread application [17, 18].

In many centers, particularly resource-limited ones, the management of pediatric intussusception lacks standardization, often relying on the experience and discretion of available staff. Until May 2016, our national pediatric center followed an ad hoc approach using either barium or hydrostatic reduction, with technique selection left to the attending surgeon and radiologist. This resulted in a modest 62% success rate for non-operative management, with some patients undergoing operative reduction based on symptom duration or the location of the intussusceptum. To address this variability, we developed a standardized modified pneumatic reduction (MPR) protocol, grounded in local resources, existing evidence, and the experience of a new attending surgeon (first author). The protocol was approved by the involved departments and has since been implemented without modification.

This study evaluates the outcomes of this MPR protocol at the sole national pediatric center. The protocol employs a hand-controlled apparatus and includes selective intravenous hydrocortisone use in specific cases. By assessing success, failure, and complication rates, this study aims to provide practical insights into optimizing non-operative intussusception management across varying resource settings.

Materials and methods

The MPR protocol for intussusception in children was implemented at the Paediatric Surgery Unit of RIPAS Hospital in May 2016. This retrospective study evaluated the outcomes of the protocol between May 2016 and October 2024, focusing on defining success, failure, recurrence, and complication rates. RIPAS Hospital serves as the sole national pediatric surgical center, with all pediatric surgical services centralized, and its integrated digital health record system captures patient presentations and follow-ups from all healthcare facilities nationwide. This robust system minimized the risk of loss to follow-up, ensuring that any late recurrences or complications were reliably documented.

The protocol outlined a structured plan for the management of intussusception (Fig. 1), which included equipment preparation, patient preparation, the reduction procedure, documentation, and post-procedure monitoring. Patients with confirmed intussusception who were hemodynamically stable and had no signs of peritonitis were managed according to this protocol. Cases managed differently or that did not adhere to the protocol were excluded from the analysis.

Equipment preparation involved assembling a two-way Foley catheter (size 20–24) connected to a combined gauge-bulb sphygmomanometer, a 30 cc syringe for balloon insufflation, and soft paraffin for lubrication. Adhesive tape was prepared to secure the buttocks after catheter placement (Fig. 2). Sedation agents (midazolam and morphine in 1 mg/mL solutions) were prepared, along with a pulse oximeter for monitoring during the procedure. A 14-gauge IV cannula was kept ready for emergency decompression of the abdomen in cases of pneumoperitoneum. In addition, a standard emergency resuscitation kit (including an intubation kit, oxygen, and adrenaline) was available for managing respiratory and hemodynamic complications.

For patient preparation, the patient's guardian was counseled regarding the procedure, potential complications, and post-procedural care, followed by obtaining informed written consent. Separate counseling and consent were required prior to any subsequent attempt of MPR, should the first attempt fail. Adequate initial resuscitation, along with the prophylactic administration of intravenous antibiotics, was provided. Sedation was achieved using midazolam (0.1 mg/kg) and morphine (0.1 mg/kg), with additional doses administered as needed during the procedure. Once the patient was adequately resuscitated, the procedure commenced.

The reduction procedure started with the insertion of a lubricated Foley catheter approximately 10 cm into the rectum. The balloon was inflated with 30 mL of air and gently pulled back until resistance was felt; this maneuver prevented any insufflation within the rectum and ensured that the balloon rested just above the upper rectum at the level of the pelvic floor. The buttocks were approximated and secured with adhesive tape to maintain the catheter position. Fluoroscopy was used to confirm proper balloon placement and the absence of pneumoperitoneum before air insufflation. Air was pumped gradually using a manual bulb, starting at a pressure of 40 mmHg and increasing to a maximum of 120 mmHg, depending on the response. If the intussusceptum began to retreat, the pressure was maintained at the effective level without further increments. *Successful reduction* was defined by the disappearance of the "claw sign" and air reflux into the ileum on fluoroscopy. Once reduction was achieved, the pressure was

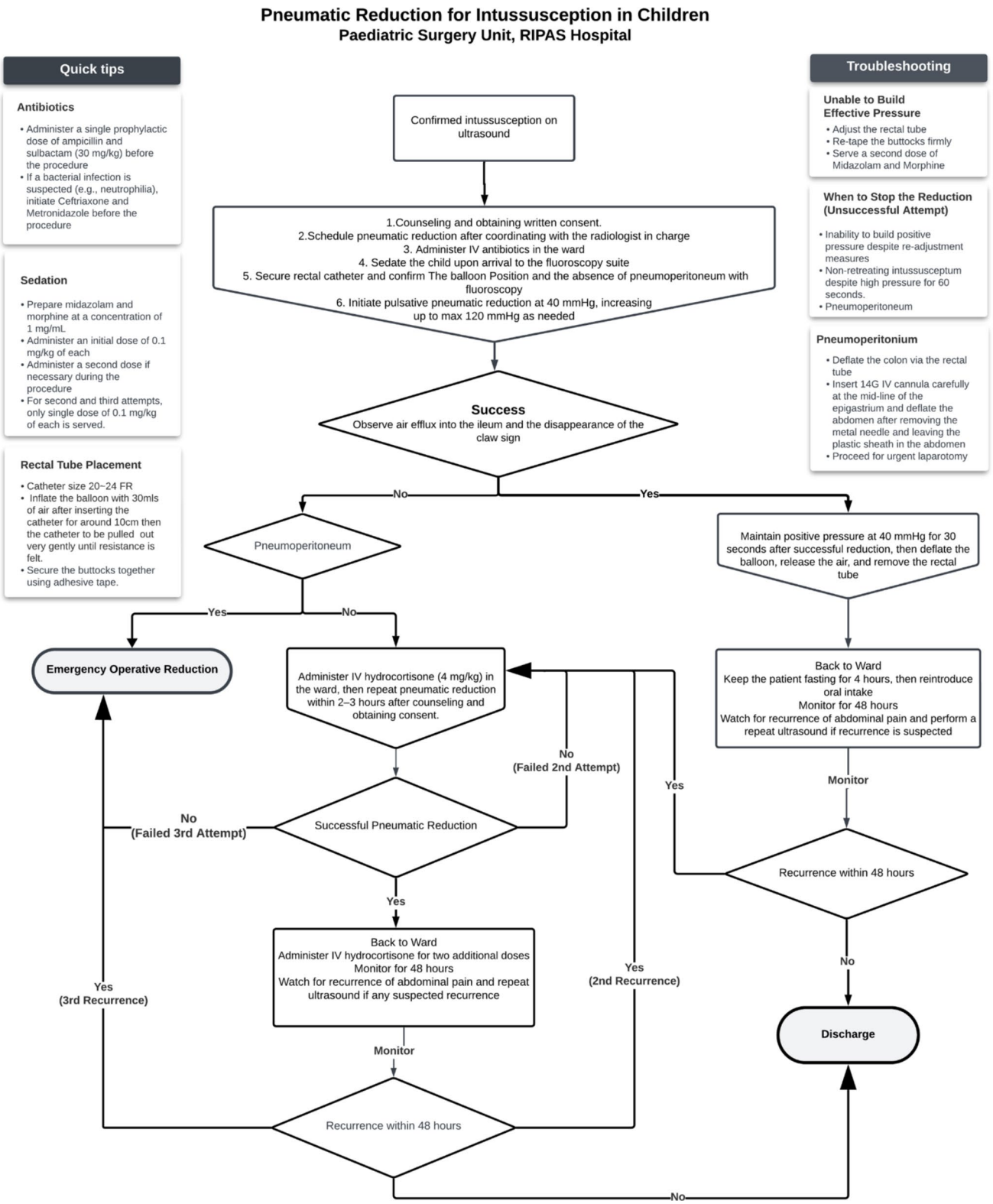

Fig. 1 Modified pneumatic reduction (MPR) protocol for intussusception. Flowchart outlining the standardized protocol implemented at the Paediatric Surgery Unit, RIPAS Hospital

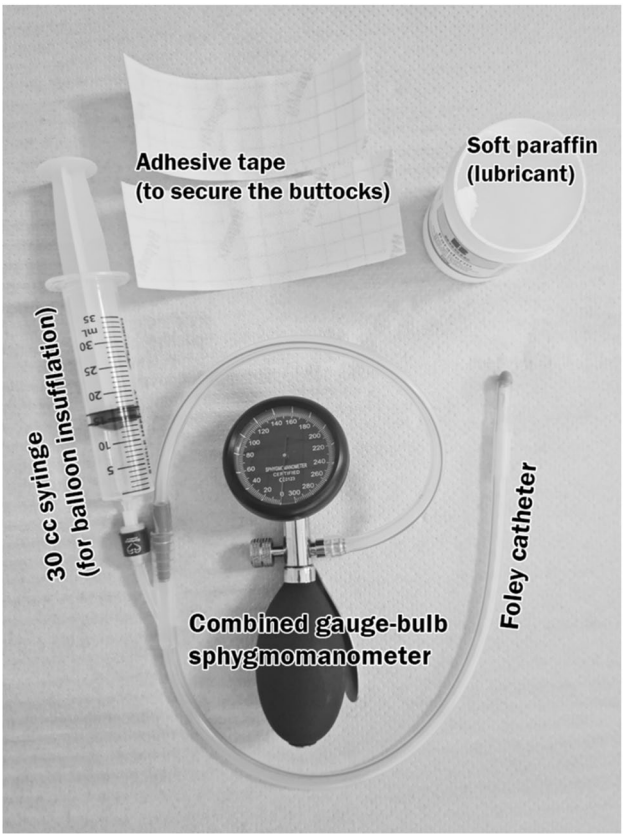

Fig. 2 Equipment used for pneumatic reduction. Shown is the assembled manual apparatus with all components

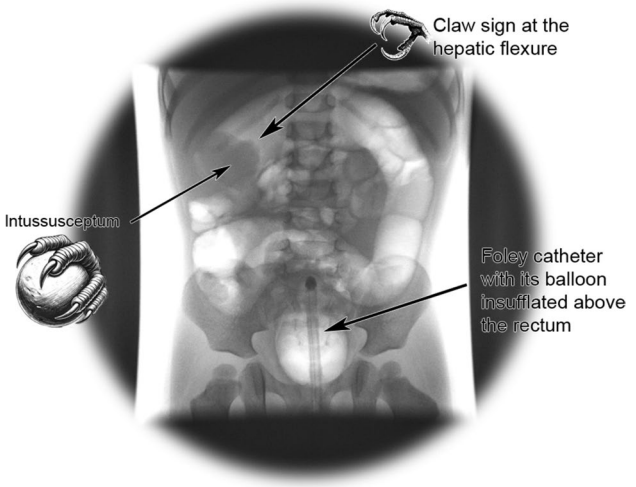

Fig. 3 The "claw sign" of an intussusceptum at the hepatic flexure. Fluoroscopic image showing a classic "claw sign" at the hepatic flexure, indicating the leading edge of the intussusceptum. A Foley catheter with its balloon is seen insufflated above the rectum, maintaining the seal for controlled air insufflation during pneumatic reduction

maintained at 40 mmHg for 30 s before gradually releasing the air, deflating the balloon, and removing the catheter.

The location of the intussusceptum was determined based on the initial position of the "claw sign" observed on fluoroscopy at the beginning of the reduction (Fig. 3). It was classified as *classic* if located proximal to the splenic flexure or *advanced* if at or distal to the splenic flexure. *The type of intussusception* was either *ileo-colic* or *ileo-ileo-colic*. For ileo-ileo-colic cases, confirmation requires identifying an ileo-ileal component following the complete reduction of the ileo-colic segment. *Pressure levels* during the procedure were categorized as *low* (40–60 mmHg), *medium* (60–90 mmHg), or *high* (90–120 mmHg). *Effective pressure* was defined as the positive pressure sufficient to achieve regression of the intussusceptum on fluoroscopy (Fig. 4). *Pressure time*, the total duration of effective positive pressure during the procedure, was recorded to the nearest 10 s, excluding time spent resolving air leaks or achieving effective pressure. An *easy reduction* is defined as an MPR requiring low or medium pressure, lasting ≤ 240 s, and needing only a single dose of sedation. Any MPR that does not fulfill this definition is deemed *difficult reduction*.

Air leaks, which were the most common cause of inability to build effective pressure, were managed by adjusting the balloon, catheter, or adhesive tape securing the buttocks. An attempt was considered failed if effective pressure could not be achieved despite these maneuvers, or if the intussusceptum ("claw sign") remained fixed at a certain location despite maintaining maximum pressure for over 60 s at that site. The *absolute failure* of MPR was determined if pneumoperitoneum occurred or if the third attempt was unsuccessful.

In cases where MPR failed without evidence of pneumoperitoneum, intravenous hydrocortisone (4 mg/kg/dose) was administered to reduce inflammation, and the procedure was repeated up to two additional times. If these attempts failed or if pneumoperitoneum developed at any stage, the patient underwent urgent laparotomy.

Post-procedure, patients were instructed to fast for 4 h before gradually resuming oral intake. The patients were monitored for 48 h to detect recurrence. *Early recurrence* was defined as symptoms and ultrasound-confirmed intussusception occurring within the same admission (48 h), while *delayed recurrence* referred to recurrence beyond this timeframe. Early recurrence was managed with repeat MPR, followed by an additional 48-h observation period.

Standardized documentation included patient demographics, presenting symptoms, initial examination findings, and the time interval between ultrasound confirmation of intussusception and MPR, rounded to the nearest 10 min. It also recorded the intussusceptum location, type of intussusception (ileo-colic or ileo-ileo-colic), pressure levels, pressure time, sedation doses, and any complications encountered.

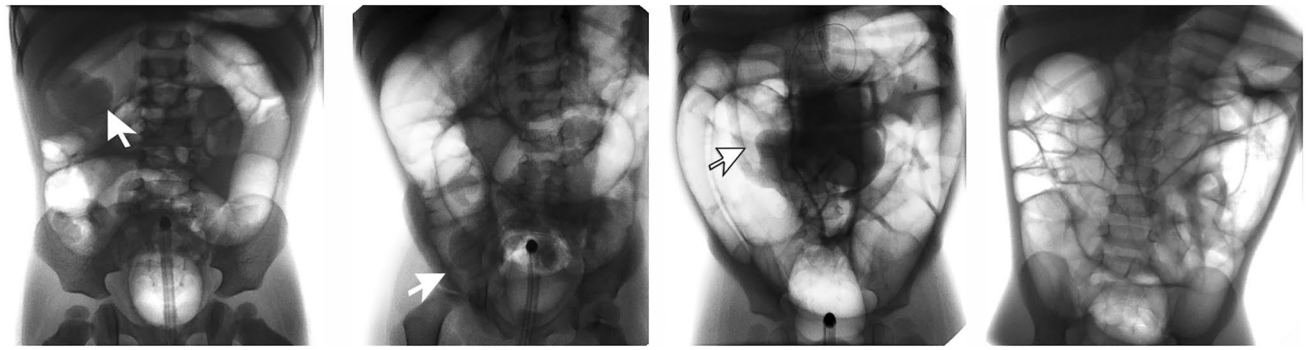

Fig. 4 Stepwise fluoroscopic reduction of an ileo-ileo-colic intussusception. Sequential fluoroscopic images illustrate the progression of pneumatic reduction. The intussusceptum (arrow) is seen retreating from the transverse colon into the caecum, marking the reduction of the ileo-colic component. This is followed by further retrograde movement into the terminal ileum, completing the ileo-ileal reduction. Successful reduction is confirmed by the disappearance of the claw sign and free air reflux into the small bowel

Demographic, clinical, procedural, and outcome data were extracted from the hospital's integrated electronic medical record system, tabulated, and independently verified. Descriptive statistics were used to summarize the dataset. Categorical variables were presented as frequencies and percentages, and continuous variables as means with ranges. Comparisons between groups were conducted using Fisher's exact test or the Chi-square test for categorical variables. In addition, logistic regression analysis was performed to identify factors associated with easy versus difficult reductions. A p value of < 0.05 was considered statistically significant.

Results

Between May 2016 and October 2024, 104 referrals for confirmed intussusception were received. After excluding 12 admissions due to non-adherence to the protocol, 92 admissions involving 79 patients were included in the analysis. These admissions resulted in a total of 107 MPRs, as some patients experienced early and/or delayed recurrence.

Among the excluded admissions, one patient underwent surgery after failing the first trial of pneumatic reduction due to a partially reduced intussusception, without re-attempting reduction as per the protocol. Another patient was directly operated on due to hemodynamic instability and a prolonged duration of symptoms, despite the absence of pneumoperitoneum. A third patient had partial reduction using a barium enema due to inconclusive ultrasound findings, followed by a successful pneumatic reduction. The remaining nine admissions were excluded due to either partial adherence or incomplete protocolized documentation; however, it is important to note that eight out of all these cases were successfully reduced.

The majority of patients were male (50/79, 64%), with an approximate mean age of 13 months (range: 3 months to 8 years). Infants under 6 months accounted for 7% of admissions (6/92), while 68% were between 6 and 18 months (63/92). A further 19% were aged 18–36 months (18/92), and 5% were older than 3 years (5/92). The mean weight for age was approximately at the 21st percentile in girls (range: 7th–80th percentile) and at the 74th percentile in boys (range: 10th–98th percentile). Most admissions occurred between May and August (63%), with a peak in June and July (39%).

The most common presenting symptom was colicky abdominal pain (76%), followed by vomiting (52%), fever (31%), blood in stools (23%), and abdominal distension (19%). An intra-abdominal mass was noted in 16% of admissions. The duration of symptoms at presentation was 1 day or less in 27% of admissions, 2–3 days in 38%, and more than 3 days in 35%. Notably, symptom durations exceeding 2 days accounted for 57% of all admissions. Further analysis revealed that in 73% of these admissions, the diagnostic interval exceeded 16 h from the time of presentation to the hospital to the confirmed diagnosis of intussusception.

The first attempt of MPR was performed at a mean time of approximately 90 min (range: 40–320 min) from the confirmation of intussusception with ultrasonography. Sedation dosing with midazolam and morphine involved 32% receiving a single dose and 68% receiving a double dose.

Ileo-colic intussusception was the most common type, observed in 101 MPRs, followed by ileo-ileo-colic intussusception in 6 cases. The location of the intussusceptum was classic in 97 cases (62% at the hepatic flexure and 38% along the transverse colon). In ten cases, the intussusceptum was advanced (two at the splenic flexure, four in the descending colon, two in the sigmoid colon, one in the rectum, and one prolapsing out of the anus). Notably, no intussusceptum was encountered in the ascending colon or caecum in our cohort.

The pressure required for reduction was low (40–60 mmHg) in 62% of cases, medium (60–90 mmHg)

in 21%, and high (90–120 mmHg) in 17%. Ileo-ileo-colic cases always required high pressure (90–120 mmHg). Classic intussusceptions generally required low pressure, with 62% being successfully reduced using this pressure. However, 21% required medium pressure, and 17% required high pressure.

The overall mean pressure time required for successful MPR was approximately 190 s. For ileo-ileo-colic intussusceptions, the mean pressure time was approximately 360 s compared to 160 s for ileo-colic intussusception. Advanced intussusceptions required a mean pressure time of 230 s. In contrast, classic intussusceptions were generally completed in a mean time of 150 s, although some cases required slightly longer durations, particularly in more challenging reductions.

MPR was highly successful, with reductions achieved on the first attempt in 97% of cases (104/107). In 2% of cases (2/107), a second attempt was required. In these instances, patients were returned to the ward after the initial procedure, received a dose of IV hydrocortisone, and underwent a second successful reduction 150 and 180 min later, respectively. Failure occurred in 1% of cases (1/107), attributed to pneumoperitoneum during the first attempt.

The failed case was a 3-month-old baby who presented with a 1-day history of blood in the stools, and the intussusceptum was encountered in the rectum and was felt on examination. Pneumoperitoneum had resulted after 50 s of medium pressure. After needle decompression of pneumoperitoneum, urgent laparotomy revealed ileo-ileo-colic intussusception with a necrotic ileocecal complex, which was resected, followed by primary anastomosis.

Complications were rare: mild desaturation (SpO_2 85–94%) occurred in 6% of MPRs, all of which resolved with supplemental oxygen. Pneumoperitoneum occurred in 1% of cases, necessitating urgent laparotomy. In addition, two cases required a second attempt, which were successful after the initial failure.

Early recurrence occurred in 16% of admissions (15/92). Among these, 9 patients experienced one episode, while 6 patients experienced two episodes, accounting for 21 recurrences. The mean interval between MPR and early recurrence was approximately 22 h (range: 18–28 h), with no recurrences occurring after 28 h. Delayed recurrence was noted in 10% of cases (8/79 patients). Of these, five patients experienced one episode, two patients experienced two episodes, and one patient experienced three episodes. The mean interval for delayed recurrence was approximately 9 months (range: 5–31 months). One patient experienced two early recurrences and one delayed recurrence, while another had one early recurrence and one delayed recurrence. All of these recurrences were recorded in patients aged less than 29 months.

In addition to the failed case, three more patients from the included cohort underwent surgical intervention. One patient underwent semi-emergency diagnostic laparoscopy due to oral intolerance after pneumatic reduction. Although recurrence was ruled out, the laparoscopy revealed significant ileal oedema and dysmotility, which resolved spontaneously with hydrocortisone and bowel rest for 3 days. Two elective laparoscopies were performed for recurrences in older children (aged 6 and 8 years), but both returned negative for lead points.

Hydrocortisone was administered prior to 23 MPRs across 17 admissions, either following a failed first attempt (2 MPRs) or to address early recurrence (21 MPRs across 15 admissions). The mean interval between the administration of IV hydrocortisone and the subsequent MPR was approximately 160 min. To assess the impact of hydrocortisone on the difficulty of the reduction, we compared the MPRs for the same admissions before and after hydrocortisone administration. In the initial MPR, 8 out of 17 cases (47%) met the criteria for an easy reduction. In contrast, after hydrocortisone administration, this proportion increased significantly to 19 out of 23 cases (83%). Statistical analysis using Fisher's exact test confirmed the improvement as significant ($p = 0.038$), with an odds ratio of 0.19 indicating a markedly reduced likelihood of difficult reductions following hydrocortisone administration.

Extending the analysis of 'easy' intussusception in relation to the duration of symptoms revealed a significant association between shorter symptom duration and easier reductions. Among patients presenting with symptoms lasting 2 days or less, 79% were classified as 'easy' reductions, compared to only 51% of those with symptoms exceeding 2 days. Fisher's exact test confirmed this association as statistically significant ($p = 0.00005$), with an odds ratio of 3.61, indicating that patients with shorter symptom durations were over three times more likely to experience an 'easy' reduction.

Multivariable logistic regression analysis revealed several trends and associations within the data. Although not statistically significant, there was a suggestive trend indicating that infants under 9 months of age were more likely to present without preceding illness but with fever and blood in stools ($p = 0.07$). Another trend was observed suggesting that younger ages (less than 14 months) were more likely to experience both early and delayed recurrence, although this did not reach statistical significance ($p = 0.054$). In addition, the absence of preceding illness was associated with a higher likelihood of recurrence, although this finding approached but did not reach statistical significance ($p = 0.059$). Double sedation dosing (0.2 mg/kg) was significantly associated with the need for higher pressures ($p = 0.01$), suggesting that more challenging reductions required both increased sedation and higher pressures. Further analysis revealed that

advanced intussusceptions, with a mean pressure time of approximately 230 s, were more likely to require medium or high pressures ($p=0.01$). No significant associations were found between any variables and the likelihood of early or delayed recurrence.

The results are summarized in Table 1.

Discussion

Pneumatic reduction is now widely accepted as the standard non-operative treatment for intussusception, with reported success rates ranging from 80 to 95% [1–7]. Our study achieved an overall success rate of 99%, among the highest reported in the literature. This was attained without any patient selection bias, underscoring the value of a meticulously standardized protocol implemented at a single national center. Regular follow-up, centralized care at a single institution, and integration of a comprehensive digital health record system supported these outcomes. Complications were uncommon and predominantly minor. Mild desaturation was observed in 6% of cases and resolved with supplemental oxygen. A single case of pneumoperitoneum (1%) required operative management.

Prior to implementing the standardized protocol, the success rate for non-operative reduction was just 62%. During the study period, cases that deviated from the protocol (i.e., the excluded cases) had a reduced success rate of 75% (3 failures out of 12). In contrast, strict adherence to the protocol yielded a markedly improved success rate of 99%, underscoring the critical importance of consistent, standardized management.

One of the critical factors contributing to the high success rate was the progressive and controlled application of pressure. Unlike traditional pneumatic reduction methods, which typically use a preset pressure (80–100 mmHg), our protocol emphasized incremental pressure adjustments based on real-time observations. Most reductions were achieved with low pressure (40–60 mmHg) in 61% of cases, minimizing the risk of complications associated with higher pressures. The

Table 1 Summary of the results and their significance

Parameter	Findings	Trend/significance
Total admissions	92 admissions (79 patients)	
Total MPRs	107 MPRs performed	
Gender	50 males (64%), 29 females (36%)	
Mean age at presentation	13 months [3 months to 8 years]	Trend: younger children are more likely to have early or delayed recurrence ($p=0.08$)
Mean weight-for-age (Asian WHO charts)	Girls: 21st percentile [7th–80th percentile]. Boys: 74th percentile [10th–98th percentile]	
Preceding illness	81% with illness, 16% with none	Trend: absence of illness associated with higher recurrence ($p=0.059$)
Symptoms	Colicky abdominal pain (76%), vomiting (52%), fever (31%), blood in stools (23%), intra-abdominal mass (16%)	Trend: infants < 9 months likely to present without preceding illness but with fever and blood in stools ($p=0.07$)
Duration of symptoms	27% ≤ 1 day, 38% 2–3 days, 35% > 3 day	Significant: shorter symptom duration (≤ 2 days) associated with easier MPR ($p=0.00005$)
Type of intussusception	101 ileo-colic, 6 ileo-ileo-colic	
Location of intussusceptum	91% classic, 9% advanced	Significant: advanced intussusception required higher pressures ($p=0.01$)
Pressure required	62% low, 21% medium, 17% high	Significant: ileo-ileo-colic always required higher pressures and longer pressure time
Mean pressure time	Overall 190 s [90–440], - Advanced: 230 s [200–380], - classic: 150 s [90–390]	Significant: advanced intussusception requires medium or high pressures ($p=0.01$)
Sedation dosing	32% single dose, 68% double dose	Significant: double sedation associated with higher pressures ($p=0.01$)
MPR success	97% first attempt, 2% second attempt, 1% failure	Failure: 1% (pneumoperitoneum during the first attempt)
Complications	6% mild desaturation, 1% pneumoperitoneum	
Early recurrence	16% of admissions (15/92), 9 patients with 1 episode, 6 with 2 episodes	Mean interval = 22 h [18–28 h]
Delayed recurrence	10% of cases (8/79), 5 patients with 1 episode, 2 with 2 episodes, 1 with 3	Mean interval = 9 months [5–31 months]

MPR modified pneumatic reduction

use of pulsatile pressure, facilitated by the hand-controlled apparatus, likely provided an additional safety margin by avoiding the sudden, continuous application of high pressure that can lead to massive pneumoperitoneum in the event of bowel perforation. This approach aligns with findings from studies by Lee et al. [9], which demonstrated the safety and efficacy of gradual pressure increments in reducing intussusception.

Pressure time is another area of debate. Traditional guidelines, derived from hydrostatic reduction experience, advocate a maximum pressure time of three minutes. However, the pulsatile nature of the manual apparatus used in this study allows for greater flexibility. As long as the "claw sign" was retreating, the procedure was continued, with pressure time extending up to 440 s in some cases. This flexibility did not result in additional complications, suggesting that the rigid time limits of earlier protocols may not be necessary when using a controlled, pulsatile pressure.

Our findings challenge several conventional contraindications for pneumatic reduction, including ileo-ileo-colic intussusception, prolonged symptom duration (> 2 days), the presence of blood in stools, and advanced locations of the intussusceptum. These factors are often cited as predictors of failure or reasons to avoid non-operative management [1, 8–11]. However, in our series, none of these factors precluded successful reduction in nearly all cases, with only one failure. For instance, ileo-ileo-colic intussusception, often regarded as a contraindication, was successfully reduced in five out of six cases. Similarly, although patients in our cohort generally presented with prolonged symptoms, all were successfully managed, including a considerable proportion classified as difficult reductions. Even advanced intussusceptions, located beyond the splenic flexure or prolapsing from the rectum, were effectively reduced. These findings underscore that pneumatic reduction should be considered in all cases without signs of peritonitis or pneumoperitoneum, regardless of intussusception type, intussusceptum location, or symptom duration.

Although prolonged symptom duration did not compromise the success of pneumatic reduction in our cohort, it reflects delays in diagnosis or referral within our healthcare system. This highlights a need for local improvements in early recognition and timely management of pediatric intussusception, which could further improve outcomes and reduce complexity and difficult reductions.

An interesting trend observed in this study involves younger infants (< 9 months). While statistical significance was not achieved, likely due to smaller numbers, these infants often presented atypically, without colicky abdominal pain or vomiting, but with fever and blood in stools. This aligns with other studies [12, 13], which highlight the need for heightened vigilance in this age group and suggest that the presence of blood in stools should prompt ultrasonography to rule out intussusception and prevent delays in diagnosis.

The recurrence rates observed in our study (16% early and 10% delayed) are consistent with the published literature [13]. While numerous studies have explored predictors of recurrence, no consensus has emerged due to inconsistent findings [9, 15–17]. In our series, none of the analyzed factors showed a significant association with recurrence, although a trend towards higher recurrence rates in younger patients was noted. This is consistent with the notion that the same pathophysiological mechanisms that predispose younger children to intussusception may also contribute to recurrence. Based on these findings, we recommend that each recurrence be treated with pneumatic reduction, reserving surgical intervention for cases with three early recurrences within the same admission, as outlined in our protocol.

The role of hydrocortisone in the management of intussusception remains debated. While some studies suggest that corticosteroids may facilitate difficult reductions and reduce recurrence rates [17, 18], others question their routine use due to limited supporting evidence [15, 18]. In our protocol, hydrocortisone was used selectively as a rescue therapy for failed initial attempts or early recurrences. Following its administration, the proportion of 'easy' reductions increased significantly from 47 to 83% ($p = 0.038$), and both patients with failed first attempts subsequently achieved successful reductions. These findings suggest a potential benefit; however, the small number of rescue cases and lack of a control group for recurrent intussusception limit the strength of this conclusion. Further studies are warranted to validate this approach and better define its role in optimizing outcomes for challenging cases.

This study supports the value of a protocol-driven approach in optimizing pneumatic reduction outcomes, even in a resource-constrained setting. The ability to achieve consistent success across a wide range of challenging presentations highlights the importance of structured processes and clinical discipline. Importantly, these findings prompt re-evaluation of exclusion criteria and encourage further investigation into the role of adjuncts such as pulsatile pressure and selective corticosteroid use. Prospective studies across varied healthcare settings are warranted to validate and expand upon these results.

Limitations

This study is limited by its retrospective design and single-center setting, which may affect the generalizability of the findings to other healthcare systems with different resources or patient populations. However, the use of a national, unified health system in Brunei, with comprehensive

documentation and centralized pediatric surgical services, reduces the likelihood of selection bias and missing data. Nevertheless, some residual bias inherent to retrospective studies cannot be fully excluded.

The sample size, while covering the entire national pediatric cohort, was relatively small and limited the power to perform more detailed subgroup analyses or detect less common outcomes.

No pathological lead points were identified in this series, which limited the ability to analyze this subgroup.

Finally, the study did not use a standardized ultrasound-based risk assessment protocol, which could have provided further prognostic information and potentially influenced management decisions.

Conclusion

This study demonstrates the effectiveness of a standardized MPR protocol in managing intussusception in children, achieving an unprecedented 99% success rate with minimal complications. The protocol's emphasis on gradual, pulsative pressure adjustments and structured management contributed to the high efficacy, even in cases with traditionally challenging features such as prolonged symptom duration, ileo-ileo-colic intussusception, and advanced locations. The findings also highlight the potential role of selective hydrocortisone use in facilitating reductions for recurrent or initially failed cases. Despite the retrospective nature and small sample size, the study underscores the feasibility of implementing such protocols in resource-limited settings and challenges conventional contraindications for pneumatic reduction. Further prospective, multi-center studies are needed to validate these findings and refine non-operative management strategies for intussusception.

Author contributions A.S. designed the study, wrote major sections of the manuscript, and oversaw the project. J.W. revised the study design, drafted the conclusion, and shared project oversight. M.A. contributed to drafting parts of the introduction and aims and performed data validation. Z.Z. drafted sections of the results and assisted with a second round of data validation. K.E. contributed to drafting the limitations and assisted with the literature review. All authors contributed to critical revision of the manuscript and approved the final version for submission.

Funding Nil.

Data availability No datasets were generated or analyzed during the current study.

Declarations

Conflict of interest The authors declare no conflict of interest.

Ethical approval This research was conducted in accordance with the Council for International Organisations of Medical Sciences (CIOMS) Ethical Guidelines. This is an observational retrospective cohort study. The Brunei Biomedical Research and Ethics Unit has given full approval to conduct this study (Reference ID: 792024).

References

1. Stein M, Alton DJ, Daneman A (1992) Pneumatic reduction of intussusception: 5-year experience. Radiology 183(3):681–684. https://doi.org/10.1148/radiology.183.3.1584915. (**PubMed+15 PubMed+15HongKongJournalofRadiology+15**)
2. Gorenstein A, Raucher A, Serour F, Witzling M, Katz R (1998) Intussusception in children: reduction with repeated, delayed air enema. Radiology 206(3):721–724. https://doi.org/10.1148/radiology.206.3.9494491
3. Beres AL, Baird R, Yousef Y, Puligandla PS, Grabowski J, Emil S (2013) Institutional analysis and systematic review with meta-analysis of pneumatic versus hydrostatic reduction for pediatric intussusception. Surgery 154(2):328–334. https://doi.org/10.1016/j.surg.2013.04.036
4. Daneman A, Navarro O (2004) Intussusception. Part 2: an update on the evolution of management. Pediatr Radiol 34(2):97–108. https://doi.org/10.1007/s00247-003-1082-7
5. Sadigh G, Applegate KE, Saindane AM (2015) Meta-analysis of air versus liquid enema for intussusception reduction in children. AJR Am J Roentgenol 205(5):W542–W549. https://doi.org/10.2214/AJR.15.14467
6. Sun J, Huang X, Li T, Yang Z, Wang X (2022) Risk factors and management process optimization for pediatric intussusception: a retrospective analysis. Front Pediatr 10:846287. https://doi.org/10.3389/fped.2022.846287
7. Vakaki M, Sfakiotaki R, Liasi S, Makris J, Papadopoulou A, Mavridis G, Gourtsoyiannis N (2023) Ultrasound-guided pneumatic reduction of intussusception in children: 15-year experience in a tertiary children's hospital. Pediatr Radiol 53(11):2436–2445. https://doi.org/10.1007/s00247-023-05730-6
8. Younes A, You J, Im YJ, Kim JH, Oh JT, Kim HY (2021) Risk factors for failed pneumatic reduction in children with intussusception: a multicenter retrospective study. Pediatr Gastroenterol Hepatol Nutr 24(1):11–16. https://doi.org/10.5223/pghn.2021.24.1.11
9. Lee DH, Kim HC, Park SJ, Kim MJ, Lee JS, Park YK, Kim WS (2012) Identifying predictive factors for successful pneumatic reduction of intussusception. Pediatr Radiol 42(9):1099–1104. https://doi.org/10.1007/s00247-011-2346-3
10. Gadgade BD, Kurbet SB, Shetty NS, Sabnis SC, Raut S, Patil V, Tiwari C (2021) Factors associated with a failed non-operative reduction of intussusception in children. J Indian Assoc Pediatr Surg 26(6):421–426. https://doi.org/10.4103/jiaps.JIAPS_297_20
11. Reijnen JA, Festen C, Harmel RP Jr (1990) Intussusception: factors related to treatment. Arch Dis Child 65(8):871–873. https://doi.org/10.1136/adc.65.8.871
12. Paul SP, Wilkinson R, Routley C, Duthie G, Basude D (2010) A case series on intussusceptions in infants presenting with listlessness. Arch Dis Child 95(5):384–386. https://doi.org/10.1136/adc.2009.160630
13. Newman J, Schuh S (1987) Intussusception in babies under 4 months of age. Can Med Assoc J 136(3):266–269
14. Niramis R, Watanatittan S, Kruatrachue A, Anuntkosol M, Buranakitjaroen V, Tongsin A, Mahatharadol V (2010) Management of recurrent intussusception: nonoperative or operative

reduction? J Pediatr Surg 45(11):2175–2180. https://doi.org/10.1016/j.jpedsurg.2010.07.029
15. Lee DH, Kim MJ, Park YK, Kim WS (2019) Identifying predictive factors for the recurrence of pediatric intussusception. Pediatr Gastroenterol Hepatol Nutr 22(2):142–151. https://doi.org/10.5223/pghn.2019.22.2.142
16. Xie X, Li L, Zhu J, Zhao L, Wang H, Liu Y (2018) Risk factors for recurrence of intussusception in pediatric patients: a retrospective study. J Pediatr Surg 53(11):2307–2311. https://doi.org/10.1016/j.jpedsurg.2018.03.023
17. Yang M, Jiang Y, Li Y, Luo J, Zhang J, Zhang H, Jin Y (2023) Risk factors and predictive models for early recurrent intussusception in children: a retrospective cohort study. Transl Pediatr. 12(10):1800–1809. https://doi.org/10.21037/tp-23-269
18. Efrati Y, Klin B, Kozer E, Abu-Kishk I (2017) The role of dexamethasone in decreasing early recurrence of acute intussusception in children: a retrospective study. J Pediatr Surg 52(7):1141–1143. https://doi.org/10.1016/j.jpedsurg.2016.12.020

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