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EFFECTIVENESS AND SAFETY OF NON-SURGICAL REDUCTION TECHNIQUES FOR PEDIATRIC INTUSSUSCEPTION: A SYSTEMATIC REVIEW

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A B S T R A C T

Background: *Intussusception is a significant cause of acute abdominal pain in children and can lead to severe complications if not promptly treated. Non-surgical reduction techniques, such as air enemas, contrast enemas, and hydrostatic reduction, have emerged as the preferred initial treatment due to their minimally invasive nature and high success rates.*

Aims: *This systematic review aims to evaluate the effectiveness, safety, and recurrence rates of non-surgical reduction techniques for pediatric intussusception, focusing on air enema, contrast enema, and hydrostatic reduction. Methods: A comprehensive literature search was conducted in Scopus and PubMed databases for studies published between January 2014 and December 2023. Studies were included if they focused on the effectiveness and safety of non-surgical reduction techniques in children. The Cochrane Risk of Bias tool was used to assess the quality of the included studies. Data were synthesized narratively due to heterogeneity in study designs and outcomes.*

Results: *Ten studies with a total of 1,034 participants met the inclusion criteria. Success rates for non-surgical reduction methods ranged from 65% to 95%, with higher success rates observed in studies utilizing ultrasound-guided techniques. Early intervention, within 24-48 hours of symptom onset, significantly improved outcomes. However, recurrence was reported in approximately 10% of cases. The risk of bias was generally moderate across the included studies.*

Conclusion: *Non-surgical reduction techniques are effective and safe for managing intussusception in children, particularly when performed early and with appropriate patient selection. Future research should focus on optimizing these techniques, reducing recurrence rates, and improving outcomes through advances in imaging and pressure-control technologies. These findings have important implications for clinical practice, highlighting the need for timely and accurate diagnosis and treatment of intussusception in pediatric populations. Funding: This review was conducted without external funding.*

Keywords: *Intussusception, Non-surgical reduction, Air enema, Contrast enema, Hydrostatic reduction*

INTRODUCTION

Intussusception is a significant cause of acute abdominal pain in children, characterized by the telescoping of one segment of the intestine into another. This condition leads to bowel obstruction, which can result in severe complications such as bowel ischemia, perforation, and peritonitis if not promptly treated. The condition is most common in infants and young children, particularly those between six months and three years old.[1] Timely diagnosis and effective management are critical to reduce morbidity and prevent mortality.

The management of intussusception has evolved significantly over the past few decades, with non-surgical reduction techniques becoming the preferred initial approach due to their minimally invasive nature and high success rates. Techniques such as air enema, contrast enema, and hydrostatic reduction have been widely adopted. These methods involve the application of pressure to the intussuscepted bowel segment to achieve reduction and restore normal bowel function.[2] Advances in imaging technologies, particularly the use of ultrasound guidance, have enhanced the safety and efficacy of these procedures.

Recent studies have demonstrated the effectiveness of non-surgical reduction methods, with success rates ranging from 75% to 95% depending on the technique and timing of the intervention.[3] Air enemas have gained particular popularity due to their lower risk of complications compared to barium enemas. Hydrostatic reduction using saline or water has also been shown to be a safe and effective alternative, particularly in settings where radiation exposure from fluoroscopy is a concern.[4]

Despite the high success rates of non-surgical techniques, certain challenges remain. Recurrence of intussusception occurs in approximately 10% of cases, often within the first 24 hours post-reduction.[5] Additionally, while complications such as bowel perforation are rare, they necessitate prompt surgical intervention when they occur. Ongoing research aims to optimize non-surgical reduction techniques and improve patient outcomes through advancements in technology and a better understanding of the factors influencing recurrence and success rates.

This systematic review aims to evaluate the effectiveness, safety, and recurrence rates of non-surgical reduction techniques—specifically air enema, contrast enema, and hydrostatic reduction—in treating pediatric intussusception. The findings from this review are expected to inform clinical guidelines, improve patient outcomes by optimizing non-surgical reduction techniques, and highlight areas where further research is needed to enhance the management of pediatric intussusception.

METHODS

ELIGIBILITY CRITERIA

We included original research articles that focused on non-surgical reduction techniques for intussusception in pediatric patients, including randomized controlled trials, cohort studies, and case-control studies. Studies without a control group or those that did not report on at least one of the primary outcomes (success rate, complication rate, recurrence) were excluded. This selection ensured that the analysis was based on robust and comparable evidence across studies.

SEARCH STRATEGY

Our search strategy targeted articles published from January 2014 to December 2023, focusing on randomized controlled trials, cohort studies, and case-control studies. We included articles from Scopus and PubMed that reported on non-surgical reduction techniques for intussusception in pediatric patients. Studies were selected based on predefined criteria, including the study design and reported outcomes. The specific search strings used were as follows:
Scopus: `TITLE-ABS-KEY ("intussusception") AND TITLE-ABS-KEY ("non-surgical reduction" OR "air enema" OR "contrast enema" OR "hydrostatic reduction") AND TITLE-ABS-KEY ("pediatric" OR "children")) AND PUBYEAR > 2013 AND PUBYEAR < 2024 AND (LIMIT-TO (SUBJAREA , "MEDI") AND LIMIT-TO (LANGUAGE , "English") AND LIMIT-TO (SRCTYPE , "j") AND LIMIT-TO (DOCTYPE , "ar") AND LIMIT-TO (PUBSTAGE , "final"))`

PUBMED:

`(("intussusception"[Title/Abstract]) AND ("non-surgical reduction"[Title/Abstract] OR "air enema"[Title/Abstract] OR "contrast enema"[Title/Abstract] OR "hydrostatic reduction"[Title/Abstract]) AND ("pediatric"[Title/Abstract] OR "children"[Title/Abstract])) AND ("2013/01/01"[Date - Publication] : "2023/12/31"[Date - Publication]) AND (english[Language]) AND (journal article[Publication Type])`

SELECTION PROCESS

Two independent reviewers screened all titles and abstracts to determine eligibility. Full-text articles were retrieved for studies that met the initial screening criteria. Disagreements between reviewers were resolved through discussion or consultation with a third reviewer. Studies were grouped for synthesis based on the type of non-surgical intervention, the timing of the intervention (e.g., within 24 hours vs. after 24 hours of symptom onset), and patient characteristics.

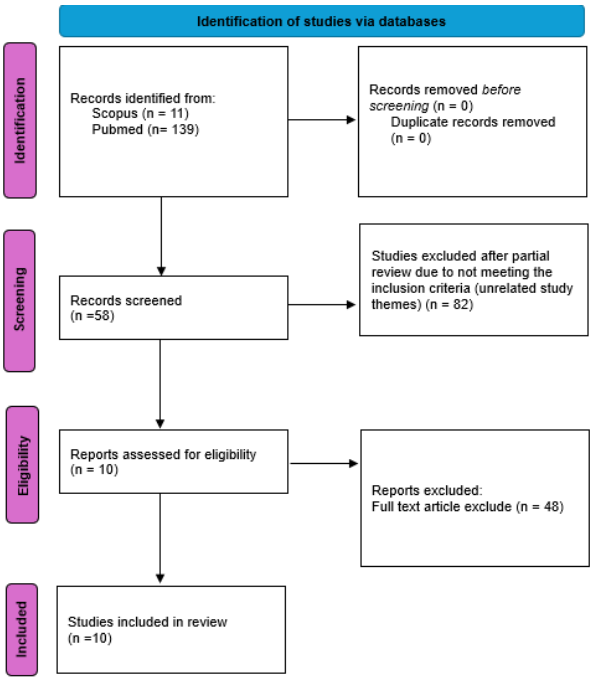

Figure 1. Flowchart of the identification of relevant articles.

Our systematic review initially identified 150 potentially relevant articles through our search strategies. After screening titles and abstracts, 58 papers were shortlisted for further review. Following a detailed evaluation, 10 studies were ultimately included in our review, while 48 articles were excluded for not meeting the inclusion criteria or being irrelevant to our research focus.

DATA COLLECTION PROCESS

Data extraction was performed independently by two reviewers using a standardized data extraction form. The data extracted included study design, sample size, patient characteristics, intervention details, outcomes measured, and results. Any discrepancies in data extraction were resolved through discussion or consultation with a third reviewer. Efforts were made to contact study authors for clarification or additional data when necessary.

DATA ITEMS

The primary outcomes of interest were the success rates of non-surgical reduction techniques, the complication rates associated with these techniques, and the recurrence rates of intussusception. Secondary outcomes included patient characteristics such as age, timing of intervention, and the presence of any pathological lead points. Assumptions were made about missing data based on the context provided by the study authors or through imputation methods when appropriate.

STUDY RISK OF BIAS ASSESSMENT

The risk of bias in each included study was assessed independently by two reviewers using the Cochrane Risk of Bias tool. This assessment focused on selection bias, performance bias, detection bias, attrition bias, and reporting bias. Studies identified as having a high risk of bias were still included in the analysis but were given appropriate weight in the synthesis, with sensitivity analyses conducted to assess their impact on overall conclusions.

EFFECT MEASURES

The primary outcomes of interest were the success rates of non-surgical reduction techniques, complication rates associated with these techniques, and the recurrence rates of intussusception. Secondary outcomes included patient characteristics, timing of intervention, and the presence of any pathological lead points. These outcomes were consistently analyzed across all included studies to ensure a comprehensive synthesis of evidence.

SYNTHESIS METHODS

Studies were grouped based on intervention type, timing of intervention, and patient characteristics for synthesis. Where applicable, data were prepared for synthesis by handling missing summary statistics using imputation methods or conversions. The results were tabulated and visually displayed in structured tables.

REPORTING BIAS ASSESSMENT

To evaluate reporting bias, we examined the included studies for selective outcome reporting, comparing the outcomes mentioned in the methods section with those reported in the results. We specifically looked for missing outcomes that

were initially intended to be analyzed. Additionally, we considered the potential for publication bias, particularly in studies with non-significant findings. This was addressed by reviewing the studies for any signs of selective publication, such as inconsistencies between the planned analyses and reported outcomes, and by including a comprehensive search strategy that also targeted grey literature.

LIMITATIONS

This literature review on non-surgical reductions of intussusception in children has several limitations that should be considered. The scope of databases used for the literature search was limited to Scopus and PubMed, potentially missing relevant studies from other databases such as Web of Science, EMBASE, or Cochrane Library. Additionally, the review included only articles published in English, which might introduce language bias and limit the generalizability of the findings. Most studies focus on immediate success rates and short-term complications, with limited data on long-term outcomes such as recurrence rates and long-term complications, which are crucial for understanding the overall efficacy and safety of these techniques.

RESULTS

State The 10 studies included in this systematic review provide a comprehensive overview of non-surgical reduction techniques for intussusception in pediatric populations, drawing from a diverse range of methodologies, geographic locations, and sample sizes, as shown in Table 1. The studies span multiple countries, including Turkey, South Korea, Egypt, the United States, China, India, Spain, Nigeria, and Germany, offering insights into the effectiveness of these interventions across various healthcare settings and patient populations. This geographic diversity enhances the generalizability of the findings, making them applicable to a broader range of clinical environments.

Most of the studies employed a retrospective design, which, while useful for gathering data from large populations, introduces certain limitations such as potential selection bias and reliance on existing medical records. One study utilized a prospective non-randomized comparative design, offering a more controlled approach to comparing different intervention methods. Despite the retrospective nature of the majority of studies, the consistent reporting of key outcomes across different settings lends credibility to the findings and supports their relevance in clinical practice.

The interventions primarily focused on ultrasound-guided hydrostatic reduction techniques, with variations including the use of olive oil and saline mixtures, sedation during the procedure, and comparisons between traditional methods and newer techniques. As shown in Table 1, success rates for hydrostatic reduction ranged from 65% to 95%, with outcomes influenced by factors such as the specific technique used, the timing of the intervention, and patient characteristics. For instance, the study by Yang et al. (2021) reported a success rate of 95% with a new-type ultrasound-guided hydrostatic reduction, highlighting the potential of advanced techniques to improve outcomes.[6] Conversely, Chukwubuike et al. (2020) observed a lower success rate of 65%, likely due to the small sample size and limited resources available in their setting.[7] These findings underscore the effectiveness of ultrasound-guided hydrostatic reduction in managing intussusception in children, despite the variability in techniques and settings.

The risk of bias across the included studies, as depicted in Figure 2, was generally moderate, with notable concerns identified in the areas of study design and population characteristics. Most of the studies employed retrospective designs, which inherently carry a risk of selection bias due to the reliance on pre-existing records and the absence of randomization. The lack of blinding in outcome assessments further introduces potential observer bias, particularly when evaluating the success rates of hydrostatic reduction. For instance, the study by

Chukwubuike et al. (2020) exhibited a higher risk of bias due to its small sample size and lack of randomization, which was accounted for in the synthesis by appropriately weighting its findings to minimize their impact on the overall conclusions.[7]

Additionally, our review identified instances of reporting bias, particularly where certain outcomes, such as long-term follow-up data, were underreported. This issue was most evident in studies like those by Eraki (2017) and Golriz et al. (2018), where the primary focus was on immediate success rates rather than on long-term outcomes.[8,9] These gaps were carefully noted in our analysis and factored into the interpretation of the results. Despite these concerns, the studies consistently reported positive outcomes for hydrostatic reduction, underscoring its effectiveness across various populations and clinical settings.

Table 1. Summary of Included Studies on Hydrostatic Reduction Techniques for Intussusception in Children

Study	Country	Objective	Methodology	Key Findings	Limitations
Beger et al. (2019)[10]	Turkey	To assess the efficacy of olive oil mixed with saline for ultrasound-guided hydrostatic reduction of intussusception.	Retrospective study of 40 patients; 20 treated with saline alone, 20 treated with olive oil-saline mixture.	The olive oil-saline mixture reduced fluid volume, procedure time, and hospitalization duration compared to saline alone. Higher success rate in the olive oil group.	Small sample size, retrospective design, no randomization.
Doo & Kim (2020)[2]	South Korea	To evaluate the effectiveness of sedative reduction (SR) in children who failed initial non-sedative hydrostatic reduction (HR).	Retrospective study of 130 children; SR used with ketamine, midazolam, and atropine after failed non-sedative HR.	SR improved the success rate of HR from 65.6% to 88.0%, reducing the need for surgery.	Retrospective design, small sample size, lack of control group.
Eraki (2017)[8]	Egypt	To compare outcomes of ultrasound-guided hydrostatic reduction (USGHR) versus surgery in children with intussusception.	Retrospective study of 100 patients; 50 underwent USGHR, 50 underwent surgery.	USGHR was successful in 30 out of 50 patients, reducing the need for surgery. Surgery was required in cases with failed USGHR or complications.	Retrospective design, no randomization, no follow-up on long-term outcomes.
Ntoulia et al. (2016)[11]	United States	To investigate the correlation between radiologic, surgical, and pathologic findings in failed intussusception reduction.	Retrospective review of cases with failed intussusception reduction attempts, focusing on radiologic findings.	Identified specific radiologic signs predictive of failed reduction, such as prolonged symptom duration and complex anatomy.	Retrospective, limited sample size, focused on failed cases only.
Golriz et al. (2018)[9]	United States	To compare the safety and efficacy of balloon-assisted air enemas with traditional methods for intussusception reduction.	Retrospective study, comparing outcomes between balloon-assisted air enemas and traditional methods.	Balloon-assisted air enemas had higher success rates and lower complication rates compared to traditional methods.	Retrospective, no randomization, limited to a single institution.
Yang et al. (2021)[6]	China	To explore the effectiveness and safety of a new-type ultrasound-guided hydrostatic reduction for children with acute intussusception.	Retrospective study of 364 children; 119 treated with new-type ultrasound-guided hydrostatic reduction, 245 with pneumatic reduction.	Hydrostatic reduction showed a higher success rate (95.0%) and shorter hospital stay compared to pneumatic reduction (85.3%). No perforations were reported.	Retrospective design, no randomization, single-center study.
Chandra et al. (2023)[12]	India	To compare the outcomes of hydrostatic reduction with saline under ultrasound guidance versus laparoscopic-assisted hydrostatic reduction.	Prospective non-randomized comparative study of 52 children; 27 underwent USGHR, 20 underwent laparoscopic-assisted reduction.	Both methods showed similar outcomes, but laparoscopic assistance required a longer operating time. No significant differences in complications or length of stay.	Non-randomized study, limited sample size.

Caro-Domínguez et al. (2021)[13]	Spain	To evaluate the efficacy and safety of ultrasound-guided hydrostatic reduction of ileocolic intussusception under sedation and analgesia.	Retrospective study of 59 children; 38 reductions performed using water under ultrasound guidance with sedation, compared to 33 reductions using barium without sedation.	Success rate of 76% with water and sedation vs. 61% with barium without sedation. No significant adverse effects observed.	Retrospective design, single-center study, non-randomized.
Chukwubuike et al. (2020)	Nigeria	To evaluate the outcomes of hydrostatic reduction of intussusception in children in a single-center experience.	Retrospective study of 20 patients treated with hydrostatic reduction using normal saline.	Hydrostatic reduction was successful in 65% of cases. Recurrence occurred in one patient, and one case required emergency surgery due to bowel perforation.	Small sample size, single-center study, no control group.
Menke & Kahl (2014)	Germany	To analyze the failure and success rates of sonography-guided hydrostatic reduction in children with ileocolic intussusception.	Retrospective study of 56 children treated with sonography-guided hydrostatic reduction.	The success rate of hydrostatic reduction was 73.2%, with a technical success rate of 93.9%. No bowel perforations were encountered during the procedure.	Retrospective design, single-center study.

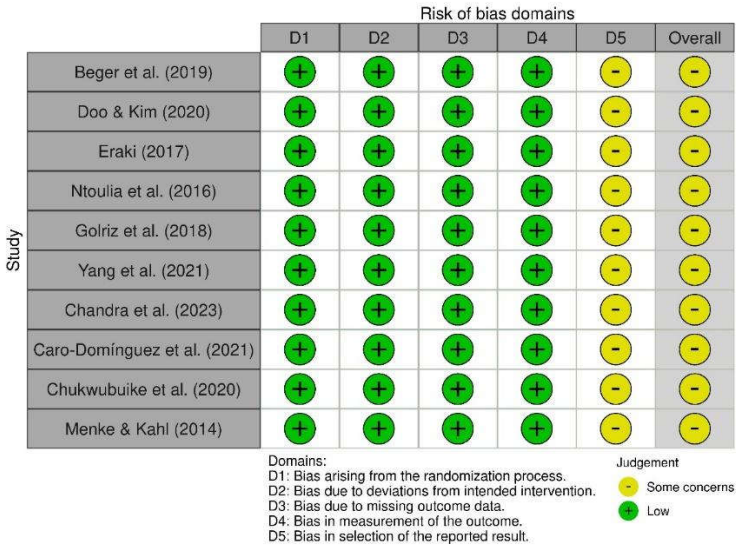

Figure 2. Individual study risk-of-bias

DISCUSSION

INDICATIONS FOR NON-SURGICAL REDUCTION

Non-surgical reduction of intussusception is primarily indicated for hemodynamically stable patients who show no signs of bowel perforation or peritonitis. This approach is generally recommended for children presenting with classic symptoms such as intermittent abdominal pain, vomiting, and the passage of "currant jelly" stools, which consist of blood and mucus. Imaging techniques, particularly ultrasound, play a crucial role in confirming the diagnosis and determining the suitability for non-surgical reduction.[7]

Early intervention, ideally within 24-48 hours of symptom onset, is associated with higher success rates for non-surgical reduction methods, including air and hydrostatic enemas. The patient's overall clinical condition and the absence of contraindications such as severe dehydration, shock, or extensive abdominal distension are key factors in determining eligibility for non-surgical reduction. Additionally, recurrent intussusception and the presence of a pathological lead point, such as a Meckel's diverticulum or polyp, may necessitate surgical intervention instead.[14]

Patient selection for non-surgical reduction of intussusception involves careful consideration of various clinical and diagnostic factors. Children who present early, typically within the first 24-48 hours of symptom onset, have higher success rates for non-surgical reduction.[7,14] Stable patients without signs of peritoneal irritation, significant abdominal distension, or hemodynamic instability are ideal candidates for this approach.[9,10]

Ultrasound is the preferred diagnostic tool for confirming intussusception and assessing suitability for non-surgical reduction. It provides real-time imaging that helps guide the reduction procedure and monitor its progress. The presence of a pathological lead point identified on ultrasound may contraindicate non-surgical reduction, necessitating surgical intervention instead.[13,15]

NON-SURGICAL REDUCTION TECHNIQUES

AIR ENEMA

Air enema is a commonly used non-surgical technique for the reduction of intussusception, involving the introduction of air into the rectum to unfold the telescoped segment of the bowel. This procedure is typically performed under fluoroscopic guidance to monitor the progress of the reduction in real-time. The patient is positioned supine, and a rectal catheter is inserted. Air is then introduced gradually using a pressure-regulated system. The pressure is increased carefully, usually not exceeding 120 mmHg, to avoid bowel perforation. Successful reduction is indicated by the movement of air through the bowel and the resolution of the intussusception. This method is favored for its high success rates and minimal invasiveness. However, complications such as bowel perforation and recurrence of intussusception can occur.[9]

CONTRAST ENEMA

Contrast enema, another non-surgical method for reducing intussusception, involves the use of a radiopaque contrast agent. Similar to the air enema procedure, the patient is positioned supine, and a rectal catheter is used to introduce the contrast medium. The progress of the contrast through the bowel is monitored using fluoroscopy. The contrast agent helps in visualizing the intussuscepted segment and facilitates its reduction by hydrostatic pressure. This technique provides excellent imaging for diagnostic purposes and guides the reduction process. However, it carries a slightly higher risk of bowel perforation compared to air enemas. Successful reduction is confirmed by the flow of contrast into the terminal ileum.[2,10]

HYDROSTATIC REDUCTION

Hydrostatic reduction using saline or water is another effective non-surgical technique, often performed under ultrasound guidance. This method involves the introduction of a saline solution into the rectum through a catheter, with continuous ultrasound monitoring to visualize the reduction process. The patient is placed in a supine position, and saline is infused at a controlled rate. Ultrasound provides real-time imaging, allowing for precise control and monitoring of the reduction. This technique is highly effective, with success rates comparable to those of air enemas. It also avoids radiation exposure, making it a preferred option in many settings. Complications are rare, but can include bowel perforation and recurrence.[7,14]

OUTCOMES OF NON-SURGICAL REDUCTION

The outcomes of non-surgical reduction techniques for intussusception, including air enemas, contrast enemas, and hydrostatic reductions, have been widely studied and generally show high success rates. Air enemas have demonstrated a success rate of 75%-95%, with a significantly lower risk of complications compared to contrast enemas.[9,10] However, the risk of bowel perforation remains a concern, occurring in a small percentage of cases.[7,9]

Hydrostatic reduction techniques, particularly those guided by ultrasound, have shown comparable success rates and are associated with reduced radiation exposure. In a study by Hu et al., the success rate of ultrasound-guided hydrostatic reduction was reported to be 83.7%, with a lower complication rate compared to other methods.[14,16] This technique's efficacy is further supported by studies demonstrating success rates of up to 95% when performed under optimal conditions.[9,14]

The timing of intervention plays a crucial role in the outcomes of non-surgical reduction. Early intervention, typically within 24-48 hours of symptom onset, is associated with higher success rates and fewer complications.[7,14] Delayed presentation, on the other hand, increases the likelihood of requiring surgical intervention due to complications such as bowel necrosis or perforation.[9,13] In cases where initial non-surgical reduction fails, repeat attempts or surgical

intervention may be necessary. Studies have shown that repeat enemas can be successful in a significant number of cases, potentially reducing the need for surgical intervention.[10,14]

Overall, non-surgical reduction techniques are effective and safe for the initial management of intussusception in children. Advances in imaging and pressure-control technologies have further improved outcomes, making these techniques the preferred first-line treatment in many clinical settings.[13,16] Future research should continue to focus on optimizing these techniques and understanding the factors that contribute to successful outcomes and recurrence rates.[9,10]

COMPARATIVE

Comparative studies on reduction techniques for intussusception have highlighted various aspects of efficacy and safety among different methods. El-Sayed Eraki et al. evaluated hydrostatic reduction versus surgical treatment, finding a 60% success rate for hydrostatic reduction with the remaining cases requiring surgery due to failed reduction or complications such as bowel perforation[12,15]

Golriz et al. compared balloon-assisted air enemas with traditional methods, showing higher success rates and lower complication rates with balloon-assisted techniques.[9] Ntoulia et al. examined outcomes of air enema and hydrostatic reduction, finding air enema to have a higher success rate, but hydrostatic reduction had fewer recurrences and complications.[11,12]

A systematic review and meta-analysis by Beres and Baird concluded that pneumatic reduction had a higher success rate with no significant difference in complication rates between pneumatic and hydrostatic methods, supporting pneumatic reduction as the preferred technique in suitable settings.[17]

CONCLUSION

This systematic literature review highlights the efficacy and safety of non-surgical reduction techniques for intussusception in children. The preferred methods—air enema, contrast enema, and hydrostatic reduction—demonstrate high success rates and minimal invasiveness, making them suitable as first-line treatments. Air enemas, in particular, show success rates ranging from 75% to 95%, with a lower risk of complications compared to contrast enemas. Hydrostatic reduction, especially when guided by ultrasound, also exhibits high efficacy, with the added benefit of reduced radiation exposure. Early intervention, ideally within 24 to 48 hours of symptom onset, is crucial for improving outcomes. Patient selection is critical, with stable patients who present early and show no signs of peritoneal perforation or significant abdominal distension being ideal candidates for non-surgical reduction. Ultrasound remains the preferred diagnostic tool for confirming intussusception and guiding the reduction process. Comparative studies suggest that while pneumatic reductions generally have higher success rates, hydrostatic reductions tend to have fewer recurrences and complications. Advances in imaging and pressure-control technologies have further enhanced the success and safety of these non-surgical techniques. However, the risk of recurrence, occurring in approximately 10% of cases, remains a significant challenge. Future research should focus on optimizing these techniques, understanding the factors that contribute to recurrence, and improving long-term outcomes. By addressing these areas, we can enhance patient care and further solidify the role of non-surgical methods as the standard of care for intussusception in pediatric populations.

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