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ORIGINAL ARTICLE

Pneumatic Reduction of Paediatric Intussusception: Clinical Experience and Factors Affecting Outcome

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ABSTRACT

Objectives: *To determine the success rate of pneumatic reduction of intussusception, and to identify factors that predict an unsuccessful outcome among Chinese paediatric patients in Hong Kong.*

Methods: *This retrospective study assessed data from Chinese paediatric patients with suspected intussusception who underwent fluoroscopy-guided pneumatic reduction at a tertiary institute in Hong Kong from January 2008 to December 2014. Pneumatic reduction of 152 intussusceptions was attempted in 137 patients (79 male, 58 female). Presenting signs and symptoms, results of radiological investigations, the outcome of attempted reduction, complications, and any subsequent surgical intervention were examined.*

Results: *Successful reduction was achieved in 115 (83.9%) cases during the study period. The mean age at presentation was 11.5 months (range, 2 months to 4.5 years). Only one (0.7%) case was complicated by perforation and 13 (9.5%) cases by early recurrence. Several predictors of failure were found, including: (a) long duration of symptoms ($p < 0.001$); (b) bleeding per rectum ($p < 0.01$); (c) evidence of small bowel obstruction at the time of presentation ($p < 0.05$). Among the 22 cases of failed reduction, surgery was performed and the findings were colocolic intussusception (n = 4), ileo-ileo-colic intussusception (n = 3), perforated ischaemic colon during pneumatic reduction (n = 1), and ileocolic intussusception (n =14). Six (4.4%) patients had lead points. Partial small bowel resection was required in seven (5.1%) cases for non-viable bowel. No deaths were recorded during the study period.*

Conclusion: *Fluoroscopy-guided pneumatic reduction of intussusception offers a high success rate (83.9%) with few complications, and our institution's radiological reduction outcomes were comparable with international standards. The most important predictor of outcome in this study was the long duration of symptoms.*

Key Words: *Child; Ileal diseases; Infant; Intussusception; Treatment outcome*

中文摘要

為腸套疊小兒患者實施空氣灌腸復位術：臨床經驗及影響結果的因素

鄧蕙碧、羅嘉齊、朱昭穎

目的：確定香港小兒患者中使用降低腸腔內壓力來治理腸套疊的成功率，並找出未能成功的因素。

方法：本研究回顧2008年1月至2014年12月期間於香港一所機構中進行腸套疊透視下空氣灌腸復位的腸套疊小兒患者的數據。137名（79男，58女）患者進行了152次腸套疊透視下空氣灌腸復位術。研

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究資料包括：患者症狀和體徵、影像學結果、復位術結果、併發症和其他後續手術干預。

結果：研究期間成功進行腸套疊透視下空氣灌腸復位術的有115例（83.9%）。患者的病發年齡平均為11.5個月（介乎2個月至4.5歲）。只有1例（0.7%）伴有穿孔的併發，另13例（9.5%）有提早復發的情況。預測腸套疊透視下空氣灌腸復位術未能成功的因素包括：（1）症狀持續時間長（p<0.001）；（2）直腸出血（p<0.01）；（3）病發時有小腸梗阻（p<0.05）。22個未能成功的病例均接受手術，發現有4例屬大腸腸套疊、3例迴腸－迴腸－結腸型腸套疊、1例進行透視灌腸復位術期間出現穿孔性缺血性結腸和14例小腸腸套疊。6名患者（4.4%）有引導病灶。7例（5.1%）不能排便的須切除部分小腸。研究期間並無死亡紀錄。

結論：腸套疊透視下空氣灌腸復位具有高成功率（83.9%），併發症少。本院的放射性腸套疊透視下空氣灌腸復位結果與國際標準相當。本研究發現腸套疊透視灌腸復位最重要的預測因素是症狀持續時間長。

INTRODUCTION

Intussusception is the most common abdominal surgical emergency in infants and toddlers, and can result in considerable morbidity and mortality if not promptly treated. There are both surgical and non-surgical methods of managing this condition; a fluoroscopy-guided contrast liquid enema technique was the first non-surgical treatment reported in 1927.[1] Other non-surgical methods introduced since then include ultrasound-guided hydrostatic or pneumatic reduction, and fluoroscopy-guided pneumatic reduction. All these methods have been tried and accepted in many countries.[2-6] Many studies suggest that fluoroscopy-guided pneumatic reduction is superior to fluoroscopy-guided liquid enema for various reasons including: it is more cost-effective and quick to perform[2-7]; it is associated with a lower radiation dose compared with hydrostatic reduction[2,3,6]; it causes less peritoneal soiling in the case of perforation[8,9]; and it has a higher success rate in many centres.[2-4,6,10]

Previous studies from Asia that examined the use of ultrasound-guided pneumatic reduction achieved a success rate of up to 95%, and demonstrated no higher rates of complications compared with other previously published techniques.[2,11-13] This method, however, failed to gain widespread support in Hong Kong; this may be due to the fact that the excellent sonographic visualisation of fluid is markedly reduced by reverberation artefacts from the inflated air, hence diminishing the original advantages of ultrasound. The first-line treatment of choice in uncomplicated cases of intussusception at our institution remains fluoroscopy-guided pneumatic reduction. The aim of this study was to determine the success rate of pneumatic reduction of intussusception in a local tertiary institute, and to identify factors that could predict an unsuccessful procedure among Chinese paediatric patients.

METHODS

This retrospective study assessed data from all Chinese paediatric patients with suspected intussusception who underwent fluoroscopy-guided pneumatic reduction at a tertiary university hospital in Hong Kong from January 2008 to December 2014. Patients were identified using the radiology department's computer database. The patients either presented to our emergency room without prior assessment or were referred to our hospital from another centre with or without prior imaging. All patients were first examined by the paediatric surgical team. After clinical assessment and review of any prior imaging, the radiology team was consulted for an ultrasound to confirm diagnosis and exclude alternative pathology. If the suspicion of intussusception was confirmed, a decision was made whether to attempt pneumatic reduction or perform surgery.

The equipment used for air enemas has changed over the years in our institution. The first procedures were performed with a hand bulb and a mercury sphygmomanometer for pressure monitoring. In recent years, a hand bulb and a digital sphygmomanometer connected to an air buffer tank has been used for more constant pressure and controlled flow of air (Figure 1). The device is connected to an appropriate-size Foley catheter that is placed in the rectum (without balloon inflation) and secured in place by taping to the buttocks. All pneumatic reductions were performed jointly by a radiologist and members of the paediatric surgical team. We followed the original British Society of Paediatric

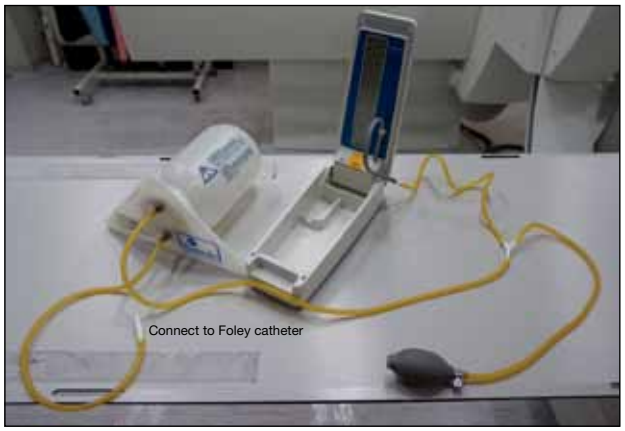

Figure 1. Equipment used for pneumatic reduction of intussusception, showing a hand bulb and a digital sphygmomanometer.

Radiology guidelines for the duration and number of attempts at reduction, i.e. three attempts for 3 minutes each, with a maximum pressure of 120 mm Hg. Variable durations and pressures were applied on an individual patient basis at the discretion of the radiologist and paediatric surgeon. All patients were examined in the supine position; they were occasionally turned prone if there was a need to hold the buttocks and provide better sealing. Sedation, antibiotics, or any other drugs were not routinely used. Negative enemas performed that did not find evidence of intussusception were excluded from analysis. Cases with shock, peritonitis, or clinical signs of perforation proceeded directly to surgery and were not part of the analysis.

The criteria for successful reduction was fluoroscopic demonstration of reduction with reflux of air into the small bowel and clinical improvement. In cases where the intussusceptum disappeared from the colon without reflux of air into the terminal ileum, the patient was monitored by the paediatric surgeons to exclude residual ileoileal intussusception. Reduction of intussusception without radiographic evidence of air entering the small bowel has been described,[14] so if the patient's symptoms disappeared, reduction was considered successful. All patients in whom pneumatic reduction failed underwent surgery.

Each case was reviewed and the following variables were evaluated: presenting signs and symptoms (clinical history and physical examination findings), results of radiological investigations, the outcome of attempted reduction (success rate and number of attempts), complications, and any subsequent surgical intervention. Those with perforation or failed air enemas had clinical notes reviewed to assess operative findings.

Statistical analysis was performed using the Statistical Package for the Social Sciences (Windows version 20.0; SPSS Inc, Chicago [IL], US). Descriptive statistics were employed to describe patient demographics and pathological findings. Chi-square test or Fisher's exact probability test, where appropriate, were used for statistical analysis. Eight variables were analysed as potential predictors of outcome: age, gender, previous history of intussusception, duration of symptoms, haematochezia, palpable abdominal mass, evidence of small bowel obstruction, and seniority of the radiologist performing the reduction. The level of statistical significance was set at $p < 0.05$.

Institutional approval has been obtained prior to commencement of the study. Due to the retrospective nature of the study, patient consent was not required.

RESULTS

Pneumatic reduction of 152 intussusceptions was attempted in 137 patients (79 male, 58 female; male-to-female ratio = 1.4:1) over the 7-year period. Negative enemas performed without evidence of intussusception (n=2), and cases that proceeded directly to surgery were excluded from analysis. All attempts were performed jointly by a radiologist (either a trainee or fellow) and members of the paediatric surgical team (at least a higher trainee or fellow).

The mean age of presentation was 11.5 months (range, 2 months to 4.5 years). Table 1 shows the age distribution in more detail. In children under the age of 12 months, reduction was successful in 81.3% (74/91 patients), while in those over 1 year old it was successful in 89.1% (41/46 patients). This difference did not reach statistical significance ($p > 0.05$).

Table 1. Distribution of age of the patients (n = 137).

Age (months)	No. (%) of patients
0 to 3	10 (7.4)
>3 to 6	38 (27.8)
>6 to 12	43 (31.5)
>12 to 18	15 (11.0)
>18 to 24	12 (8.9)
>24 to 30	7 (5.1)
>30 to 36	5 (3.4)
>36	7 (4.9)

Table 2. Success rates during 2008 to 2014.

Year	Success rate (%)
2008 (n=19)	79
2009 (n=18)	82
2010 (n=25)	85
2011 (n=15)	83
2012 (n=17)	85
2013 (n=23)	88
2014 (n=20)	85
Overall (n=137)	83.9

Successful reduction was achieved in 115 (83.9%) cases during the study period. Table 2 shows the success rate according to year; the highest rate of success was achieved in 2013 (88%) and the lowest in 2008 (79%); the differences were not statistically significant. Thirteen (9.5%) of the 137 patients were complicated by early recurrence (recurrence within 1 week of the initial episode) and underwent multiple attempted reductions — two patients underwent three, and 11 patients underwent two attempted reductions. The head of the intussusception was seen in the caecum in three (2.0%) cases, the ascending colon in 48 (31.6%), the transverse colon in 92 (60.5%), and the descending colon in 9 (5.9%).

The duration of symptoms varies with a mean duration of 1.8 days prior to presentation; 33.3% of patients (16/48) who had been symptomatic for ≥2 days failed pneumatic reduction, whereas only 6.7% of patients (6/89) who presented <2 days after becoming ill failed reduction ($p < 0.001$).

The classical presentation of intussusception is abdominal pain, vomiting, and the passage of 'red currant jelly' stool. In this study, the presenting symptoms and signs were pain in 132 (96.4%) cases, rectal bleeding (haematochezia) in 45 (32.8%), abdominal mass in 56 (40.9%), and vomiting in 39 (28.5%). The success rate of pneumatic reduction was 71.1% (32/45) for patients with rectal bleeding and 90.2% (83/92) for those without haematochezia ($p < 0.01$).

A palpable abdominal mass was the main physical sign in intussusception. It was documented as present in 51.8% (71/137) of the patients, but no significant difference was found between the groups with successful and those with failed pneumatic reduction. There was also no significant difference in the incidence of abdominal pain or vomiting.

Figure 2. Abdominal radiograph in a 3-year-old male patient with ileocolic intussusception. A crescent sign is noted at the right lower quadrant that corresponds to the head of the intussusceptum (arrow). Mild dilatation of the proximal small bowel loops is also seen (arrowhead).

An abdominal radiograph was available in 118 patients, of which 87 were abnormal (e.g. with soft tissue mass visible) and 56 showed radiographic evidence of small bowel obstruction (Figure 2). Therefore, small bowel obstruction was present in 40.9% (56/137) of patients, but was seen in 77.3% (17/22) of those with failed reduction ($p < 0.05$).

Information regarding the seniority of the radiologist performing the reduction was available for all cases. Cases undergoing attempted pneumatic reduction during non-office hours were typically performed by a radiology trainee (i.e. the on-call radiologist), whereas those attempted during office hours were performed by radiology trainees and/or specialists. In all cases, members of the paediatric surgical team were present and actively participated in the procedure. Overall, 47 reductions were performed by specialists or under specialist supervision with a success rate of 83.9% (47/56 cases), while 80 reductions were performed by radiology trainees alone with a similar success rate of 83.3% (80/96 cases).

Among the 22 cases of failed reduction, surgery was performed for manual reduction and the findings were: four cases of colocolic intussusception, three cases of ileo-ileo-colic intussusception, one with perforated ischaemic colon during pneumatic reduction and the remainder with ileocolic intussusception (Table 3). Pathological specimens were available in six (4.4%) patients with lead points: colonic polyp in one, inflammatory pseudopolyp in four, and a mural haematoma in one. Partial small bowel resection was required in seven (5.1%) cases for non-viable bowel. Two patients had wound complications (i.e. wound dehiscence and wound infection), one patient had bowel volvulus and another patient had an intra-abdominal collection necessitating further surgery. The remaining 18 patients made an uneventful recovery with normal development and weight gain documented at last follow-up. No deaths were recorded during the study period.

There were a small number of complications related to pneumatic reduction. Only one (0.7%) patient had a perforation during pneumatic reduction during the study period. She was 9 months old with a 3-day history of intermittent abdominal pain, vomiting, and rectal bleeding before presenting to hospital. The perforation occurred early in the attempted reduction at relatively low pressure (up to 95 mm Hg as documented in the radiology report). It was promptly recognised by the radiologist and the patient proceeded directly to surgery. At surgery, she was discovered to have one small perforation in an ischaemic area of colon. The perforation was repaired and she eventually made a full recovery.

DISCUSSION

Intussusception is one of the most common causes of abdominal pain and intestinal obstruction in infants. The great majority of cases occur in children under the age of 2 years and most are ileo-colic. Less than 10% of cases have a pathological lead point, and there is a 2:1 male predominance.[15] Our patients showed a small male majority with less than 5% demonstrating a lead point at surgery, but were otherwise a fairly typical group of intussusception patients.

Table 3. Surgical findings in cases with failed pneumatic reduction.

Finding	No. of patients (n = 22)
Perforated ischaemic colon (during pneumatic reduction)	1
Ileo-ileo-colic intussusception	3
Colocolic intussusception	4
Ileocolic intussusception	14

The overall success rate of pneumatic reduction was 83.9%, with a slight gradual improvement in the success rate of reduction over the years of study. This was probably due to increased experience with improved technique and equipment, and may also account for the high success rate of 88% in 2013 (Table 2). Our reduction rate was comparable with the 77.2% reduction rate achieved in a similar local case series,[16] and comparable with the rates achieved in the international literature published from North America,[3,4] China,[13] and Japan[12]; it was also considerably higher than the recently published national reduction rate of only 71% achieved in the United Kingdom.[17] Some authors have criticised the high reduction rates of over 90% described in large Chinese series as being due to selection bias. For example, Guo et al[18] excluded newborn infants, cases with signs and symptoms for >60 hours, dehydrated or very ill patients, and cases with significant rectal bleeding. Zhang et al[19] regarded a history of signs and symptoms for >48 hours, blood per rectum or a large palpable mass as contraindications to pneumatic reduction. Daneman and Navarro[20] reviewed all aspects of intussusception and although they could not conclude which was the most successful technique, they did suggest that a reduction rate of 80% to 90% should be achievable. Ko et al[21] made similar conclusions in 2007 that a 90% reduction rate should be achievable, but their study was limited to idiopathic cases where better results are expected.

In this study, the success rate was higher in children over the age of 1 year (89.1%) compared with children under 1 year (81.3%), but the difference did not reach statistical significance in this study. The literature has reported lower success rates in very young infants because of a higher incidence of pathological lead points,[22] irreducibility,[23] and perforation.[6] It is worthwhile to note that success rates in the literature are also lower in children over 2 years of age.[24]

Our results demonstrated three significant predictors of the success of reduction. These are, in descending order of importance, a long duration of symptoms, per rectal bleeding, and evidence of small bowel obstruction at the time of presentation. Conversely, no significant relationship was found between failed reduction and

Table 4. Factors significantly associated with the outcome of pneumatic reduction.

Variable	% of successful enemas	p Value
Symptoms (<48 hours vs. >48 hours)	94 vs 67	<0.001
Per rectal bleeding (no vs. yes)	71 vs 90	<0.01
Small bowel obstruction (present vs. absent)	42 vs 86	<0.05

Table 5. Factors with no significant effect on the outcome of pneumatic reduction ($p > 0.05$).

Age at presentation
Sex of the patient
Previous history of intussusception
Presence or absence of a palpable abdominal mass
Seniority of the radiologist performing pneumatic reduction

the age or gender of the patient, previous history of intussusception, the presence of a palpable mass, or seniority of the radiologist (Tables 4 and 5).

In a recent retrospective case series by Wong et al[16] performed at another tertiary referral centre in Hong Kong, the presence of a palpable abdominal mass was found to be the only statistically significant factor predicting unsuccessful non-operative reduction of intussusception. The authors postulated that a palpable mass may signify longer duration of intussusception thus rendering non-operative reduction less successful, due to intestinal obstruction and consequent difficulty for the reduction medium to pass through.[16] While a palpable abdominal mass did not predict failure of reduction in our study, our data supported the implication that a longer duration of intussusception is associated with an adverse outcome. Wong et al[16] also concluded that the duration of presenting symptoms and presence of per rectal bleeding did not significantly affect the chance of a successful non-operative reduction, which is contrary to our findings. The difference in results from our study may be partly due to their inclusion of both hydrostatic and pneumatic reduction cases in the analysis. In addition, non-operative reductions in the case series were performed by radiologists with a paediatric surgeon available only if necessary, whereas in our institution, all pneumatic reductions were performed jointly by radiologists and paediatric surgeons.

The most important predictor of outcome in this study was a long duration of symptoms; a number of authors have previously reported that the duration of symptoms is a significant predictor of outcome.[6,24,25] One-third (16/48) of the cases with symptom duration of >48 hours failed attempted pneumatic reduction whereas it was successful in over 90% (83/89 patients) of those with symptom duration of <48 hours. The patient complicated by bowel perforation was symptomatic for 3 days before presenting to hospital. These findings suggest that patients symptomatic for over 2 days should be considered high risk for failed pneumatic reduction. Delay in presentation can be incurred by the parents in some cases and by peripheral hospitals in others.[26] It may be difficult to influence the individual parent to present the child earlier; but in a peripheral hospital, greater awareness of the significance of subtle features of intussusceptions with regard to early referrals can positively influence the outcome.

Rectal bleeding was also a significant predictor of reduction failure. This is in keeping with previous findings.[6,25] Haematochezia is likely a result of mucosal ulceration associated with bowel wall ischaemia. A previous study by Reijnen et al[27] calculated that patients with both haematochezia and symptoms lasting >48 hours had a greater-than-92% chance of failed reduction. Among the 22 patients with failed reduction in this study, a great majority (18 patients) indeed had this combination, including the one patient who was complicated by perforation during attempted pneumatic reduction. Reduction in these patients should be attempted with caution, due to the risk of perforation, and they should be observed carefully in the post-reduction period for recurrent symptoms consequent to ischaemic damage to the bowel.

Small bowel obstruction was the third predictor of reduction failure in this study; greater than two-thirds of the 22 cases of intussusception (occurring in 17 patients) with failed reduction demonstrated small bowel obstruction on abdominal radiograph. The presence of small bowel obstruction at presentation may be an indirect indication of the chronicity of intussusception, where a longer clinical history results in greater bowel

wall oedema and consequent development of proximal obstruction. There were no complications as a result of attempting reduction in this group.

There was no significant difference in the success rate for reduction by trainees versus specialist radiologists. In our institution, a team approach is used with active involvement of the paediatric surgical team, thus optimising the combined experience and skills of surgeons and radiologists. A retrospective review by Okazaki et al[28] investigated personnel performing reduction and also supported the active role of the surgeon. They demonstrated a 30% increase in reduction rates when cases were performed by the consultant surgeon rather than the radiologist, and one of the highest reduction rates in the literature of 94% was achieved in the hands of the surgeon.[28] Okazaki et al[28] concluded that in the absence of a surgeon, who can deal with the potential problems of perforation or patient deterioration, radiologists may be more cautious in reduction, hence achieving lower rates.

The main complication of pneumatic reduction is bowel perforation, and perforation rates are discussed in the literature as a marker of performance and safety.[18-21] Our perforation rate of 0.7% was in accordance with other reported rates of approximately or less than 1%.[18-21] In cases with perforation, air is safer than barium in the peritoneal cavity, although tension pneumoperitoneum can be a fatal complication that occurs exclusively with gas.[29-32] Rapid haemodynamic and respiratory deterioration can occur, even death.[18] An 18-Gauge needle should be readily available to rapidly decompress the high intra-abdominal pressure if required. Similar case was not encountered in our study.

One of the problematic areas with air enema is the difficulty in identifying lead points, which may be better delineated with contrast in hydrostatic reduction. Some authors advocate that in cases of multiple recurrences, a barium enema may be required.[6] In this study, patients with failed pneumatic reduction proceeded directly to surgery and six (4.4%) patients were found to have lead points in the operating theatre. Another problematic area is that reflux of air into the small bowel does not always occur after successful reduction, and residual ileoileal intussusception cannot be excluded without reflux. In this study, cases with apparent reduction without reflux were observed by the paediatric surgical team, and if the patients remained stable with symptomatic resolution, pneumatic reduction was considered successful.

In the current literature, ultrasound-guided techniques are gaining attention due to their many advantages over fluoroscopy-guided techniques. Ultrasound is highly accurate in monitoring the reduction process as well as in evaluating post-reduction residual intussusception and possible lead points,[33-40] but it is the lack of ionising radiation that is its most important advantage over all X-ray methods. In 1982, Kim et al[41] already reported successful ultrasound-based reduction of intussusception with a saline enema, and they achieved high reduction rates of 80% to 90%. Ultrasound-based hydrostatic reduction techniques have not achieved popular use locally, however. Unfortunately, care providers may still prefer the reduction method that they are used to, regardless of the ALARA (as low as reasonably achievable) principle.[42]

CONCLUSION

Pneumatic reduction of intussusception offers a high success rate with few complications, and our institution's radiological reduction outcomes were comparable with international standards. The most important predictor of outcome was a long duration of symptoms; therefore, performing an air enema earlier in the course of the disease may increase the chance of successful reduction and reduce morbidity. Other predictors included haematochezia and evidence of small bowel obstruction at the time of presentation. An infant with symptom duration of >48 hours and rectal bleeding should be considered a high-risk patient and managed with great care.

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