Clinical prediction rules for failed nonoperative reduction of intussusception

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Purpose: The nonoperative reduction of intussusception in children can be performed safely if there are no contraindications. Many risk factors associated with failed reduction were defined. The aim of this study was to develop a scoring system for predicting the failure of nonoperative reduction using various determinants.

Patients and methods: The data were collected from Chiang Mai University Hospital and Siriraj Hospital from January 2006 to December 2012. Inclusion criteria consisted of patients with intussusception aged 0–15 years with no contraindications for nonoperative reduction. The clinical prediction rules were developed using significant risk factors from the multivariable analysis.

Results: A total of 170 patients with intussusception were included in the study. In the final analysis model, 154 patients were used for identifying the significant risk factors of failure of reduction. Ten factors clustering by the age of 3 years were identified and used for developing the clinical prediction rules, and the factors were as follows: body weight <12 kg (relative risk [RR] =1.48, P=0.004), duration of symptoms >48 hours (RR =1.26, P<0.001), vomiting (RR =1.63, P<0.001), rectal bleeding (RR =1.50, P<0.001), abdominal distension (RR =1.60, P=0.003), temperature >37.8°C (RR =1.51, P<0.001), palpable mass (RR =1.26, P<0.001), location of mass (left over right side RR =1.48, P<0.001), ultrasound showed poor prognostic signs (RR =1.35, P<0.001), and the method of reduction (hydrostatic over pneumatic, RR =1.34, P=0.023). Prediction scores ranged from 0 to 16. A high-risk group (scores 12–16) predicted a greater chance of reduction failure (likelihood ratio of positive [LR+] =18.22, P<0.001). A low-risk group (scores 0–11) predicted a lower chance of reduction failure (LR− =0.79, P<0.001). The performance of the scoring model was 80.68% (area under the receiver operating characteristic curve).

Conclusion: This scoring guideline was used to predict the results of nonoperative reduction and forecast the prognosis of the failed reduction. The usefulness of these prediction scores is for informing the parents before the reduction. This scoring system can be used as a guide to promote the possible referral of the cases to tertiary centers with facilities for nonoperative reduction if possible.

Keywords: intussusception, nonoperative reduction, failure rate, clinical prediction rules

Introduction

Intussusception was a common cause of bowel obstruction and lower gastrointestinal bleeding in infants and children with an incidence of one to four in 2000.1 The invagination of one part of the intestine into another distal part causes intussusception. Two of the most common symptoms are vomiting and colicky abdominal pain. In addition, the two most common signs are abdominal mass and rectal bleeding.1 The diagnosis of intussusception can be determined by ultrasound with 100% accuracy by an experienced...
examiner and according to the clinical case definition for the
diagnosis of acute intussusception proposed by the Brighton
Collaboration Intussusception Working Group.2

Currently, treatment modalities for intussusception
comprise nonsurgical and surgical treatment. The attempt of
nonsurgical treatment is performed if no contraindications are
present, which include signs of perforation (peritonitis, pneu-
mosperitoneum in a plain abdominal X-ray) and a hemody-
amically unstable patient in spite of adequate resuscitation.
Surgical treatment is performed when nonsurgical treatment
is contraindicated or has failed. The nonsurgical reduction
procedure can be performed by hydrostatic or pneumatic
pressure enema under ultrasound or fluoroscopy.

The diagnosis and treatment methods vary around the
world depending on resources and equipment. In 2013,
Jiang et al reviews the diagnosis and the treatment of
intussusception. The findings indicated that 95%–100% of the cases were diagnosed by
a radiographic study (air contrast enema, ultrasound, or
computed tomography) in all the World Health Organization
regions except Africa where 65% of cases were diagnosed by
clinical findings or surgery. The global incidence of treat-
ment with air or barium enema accounted for 66%. In Africa
and Central and South America, the primary treatment was
surgery. In recent reports of some areas, surgery was still
the primary treatment.4

The reported success of nonsurgical reduction in the litera-
ture ranged from 46% to 94%.5 Risk factors associated with
failed reduction were studied in some series. In 2014, He et al6
reported that initial intussusception was located in the descend-
ing colon/rectum with the presence of peritoneal fluid, trapped
fluid in the intussusception, and bloody stools as the factors.
In 2013, Fallon et al7 described the predictors of abdominal
symptoms >2 days, age <1 year, and multiple ultrasound
findings. Our earlier series studied the prognosis indicators for
failed reduction and found that body weight <12 kg, duration of
symptoms >3 days, vomiting, rectal bleeding, abdominal
distension, temperature >37.8°C, palpable abdominal mass,
location of mass on the left side, ultrasound showing poor
prognostic signs, and the method of reduction (hydrostatic
over pneumatic) were the factors.8

Many factors seem to influence successful or failed reduc-
tion. In this study, we aimed to develop a scoring system for
predicting the failure of nonsurgical reduction using various
determinants that were found in the earlier studies.

Patients and methods
This retrospective cohort study was approved by the ethics
committees of Chiang Mai University (CMU) Hospital and
Siriraj (SI) Hospital. Due to the retrospective nature of this
study, both committees waived the need for patient consent.
This study was the third study in cluster of study series
regarding intussusception. The first study reported compara-
tive results of the success rates of hydrostatic and pneumatic
reduction.9 The second study reported the prognostic indica-
tors of failed operative reduction.8 This was the third study
that used ten prognostic factors for failed nonsurgical reduc-
tion derived from the second study.

Patients
This was a two institution review. The data were collected
from patient charts and electronic medical records of the
patients with intussusception (ICD-10 code K56.1) in CMU
and SI. The study period was between January 2006 and
December 2012. We included the patients who were diag-
osed with intussusception from the age of 0 year to 15 years
who received nonsurgical reduction as an initial treatment.

We excluded patients who had contraindications for nonsur-
gical reduction at presentation. Absolute contraindications
were peritonitis, pneumoperitoneum in abdominal X-ray, and
hemodynamic instability. The method of nonsurgical reduc-
tion in CMU was all pneumatic reduction under fluoroscopy,
whereas the main method of reduction in SI was hydrostatic
reduction under fluoroscopy by radiologist. Thus, the method
of reduction could be used as one of the predictors.

Predictive variables
The chart and electronic database reviews collected the data
of following ten significant factors: body weight, duration of
symptoms, vomiting, rectal bleeding, abdominal distension,
temperature, palpable abdominal mass, location of mass,
ultrasound showed poor prognostic signs, and the method of
reduction. The demographic data such as age and sex were
also collected. Poor prognostic signs by ultrasound were a
thick peripheral hypoechoic rim, free intraperitoneum fluid,
fluid trapped within the intussusception, enlarged lymph node
in intussusception, pathologic leading point, and the absence
of blood flow in the intussusception, and were counted if one
of these signs mentioned was present.

Outcome variables
The results of the nonsurgical reductions were collected. The
patients were divided into two groups: a successful reduction
group and a failed reduction group.

Statistical analysis
The statistical analysis was performed by using commercial
statistical software (STATA 11.0; StataCorp LP, College
Station, TX, USA). The data were presented in count and
percentage. The univariable comparative statistics were performed by Fisher’s exact test for categorical data and by Student’s t-test or Mann–Whitney U-test for continuous data depending on data distribution. Generalized linear model for exponential risk regression clustering by the age of 3 years (due to the risk for pathologic leading point) was used for multivariable analysis.

Ten significant risk factors were used for the clinical prediction model for failed reduction of intussusception derivation. Numerical factors such as body weight, duration of symptoms, and temperature were divided into two groups. The cutoff points were determined from the values that yielded all statistically significant regression coefficients and the highest area under the receiver operating characteristic (ROC) curve of the logistic regression model.

The regression coefficients of each factor were transformed into item scores. All item scores were added together for a total score. The total scores were used as a predictor for failed nonsurgical reduction of intussusception. The risk level was to categorize total scores into a low-risk group and a high-risk group. The cutoff points for the total scores were determined from the values that yielded the lowest likelihood ratio of positive for failed reduction in the low-risk group and highest likelihood ratio of positive for failed reduction in the high-risk group. The statistical significance level was set as two tailed with a P-value of <0.05.

**Results**

A total of 190 episodes of intussusception were collected from two institutions. Primary surgery at first visit was performed in 20 patients due to contraindications for nonsurgical reduction. According to the retrospective study, some of the missing data were found in 16 records. A total of 154 episodes of intussusception were collected for final prediction model analysis. The median age of the included patients was 9 months (maximum 124 months). There were 114 boys (67%) and 56 girls (33%). The comparative characteristics of 170 patients with intussusception who had successful reductions and failed nonsurgical reductions are shown in Table 1. The mean weight was significantly lower in the failed group (mean 8.61±1.98 in the failed group vs mean 10.15±3.90 in the successful group, *P*=0.002). Rectal bleeding and abdominal distension were found more in the failed group (58.18% vs 41.82%, *P*=0.020). Hydrostatic reduction was also found more frequently in the failed group (55.93% vs 44.07%, *P*=0.036). The median duration of symptoms, palpable abdominal mass, and ultrasound findings with poor prognostic signs were not significantly different in univariable analysis.

Ten prognostic factors were identified from the earlier studies with statistical differences between the failed and successful reduction groups in multivariable analysis by exponential risk regression, which are shown in Table 2. Risk scoring assignment was performed to forecast the possibility of a failed nonsurgical reduction of intussusception. The regression coefficients were transformed to transform coefficients by dividing with the smallest coefficient in the model which was 0.23 and then rounded up to the nearest integer to be an assigned score. The Item Scoring Scheme is shown in Table 3. The total scores ranged from 0 to 16.

After using the ten parameters that were transformed into a score, the ROC curve of the failed nonoperative reduction of intussusceptions predicted by risk scoring scheme was performed. The area under the ROC curve that determined the failed group (58.18% vs 41.82%, *P*=0.020). Hydrostatic reduction was also found more frequently in the failed group (55.93% vs 44.07%, *P*=0.036). The median duration of symptoms, palpable abdominal mass, and ultrasound findings with poor prognostic signs were not significantly different in univariable analysis.
Table 2 Regression coefficient, RR, and 95% CI of selected risk indicators for failed reduction of intussusceptions derived from generalized linear model

<table>
<thead>
<tr>
<th>Risk indicators</th>
<th>Coefficients</th>
<th>RR</th>
<th>95% CI of RR</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight ≤12 kg</td>
<td>0.39</td>
<td>1.48</td>
<td>1.13–1.94</td>
<td>0.004</td>
</tr>
<tr>
<td>&gt;12 kg</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Duration of symptoms ≤48 hours</td>
<td>0.23</td>
<td>1.26</td>
<td>1.25–1.26</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>&gt;48 hours</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Vomiting</td>
<td>0.49</td>
<td>1.63</td>
<td>1.54–1.73</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Rectal bleeding</td>
<td>0.41</td>
<td>1.50</td>
<td>1.20–1.89</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Abdominal distension</td>
<td>0.47</td>
<td>1.60</td>
<td>1.18–2.17</td>
<td>0.003</td>
</tr>
<tr>
<td>Temperature &gt;37.8°C</td>
<td>0.41</td>
<td>1.51</td>
<td>1.47–1.55</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Palpable mass</td>
<td>0.23</td>
<td>1.26</td>
<td>1.24–1.28</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Location (left over right side)</td>
<td>0.39</td>
<td>1.48</td>
<td>1.40–1.56</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ultrasound (poor prognosis sign)</td>
<td>0.30</td>
<td>1.35</td>
<td>1.29–1.42</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Method of reduction (hydrostatic over pneumatic)</td>
<td>0.29</td>
<td>1.34</td>
<td>1.04–1.71</td>
<td>0.023</td>
</tr>
</tbody>
</table>

Abbreviation: RR, relative risk.

Table 3 Item scoring scheme for predictors for failure reduction of intussusception derived from coefficients of selected indicators

<table>
<thead>
<tr>
<th>Risk indicators</th>
<th>Coefficients</th>
<th>Transformed coefficients</th>
<th>Assigned score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight ≤12 kg</td>
<td>0.39</td>
<td>1.70</td>
<td>2</td>
</tr>
<tr>
<td>&gt;12 kg</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Duration of symptoms ≤48 hours</td>
<td>0.23</td>
<td>1.78</td>
<td>1</td>
</tr>
<tr>
<td>&gt;48 hours</td>
<td>–</td>
<td>–</td>
<td>1</td>
</tr>
<tr>
<td>Vomiting</td>
<td>0.49</td>
<td>2.13</td>
<td>2</td>
</tr>
<tr>
<td>Rectal bleeding</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Yes</td>
<td>–</td>
<td>1.78</td>
<td>2</td>
</tr>
<tr>
<td>Abdominal distension</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Yes</td>
<td>0.41</td>
<td>2.04</td>
<td>2</td>
</tr>
<tr>
<td>Temperature &gt;37.8°C</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Yes</td>
<td>0.41</td>
<td>2.04</td>
<td>2</td>
</tr>
<tr>
<td>Palpable mass</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Yes</td>
<td>0.23</td>
<td>1.78</td>
<td>2</td>
</tr>
<tr>
<td>Location</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Right</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Left</td>
<td>0.39</td>
<td>1.70</td>
<td>2</td>
</tr>
<tr>
<td>Ultrasound (poor prognosis sign)</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Yes</td>
<td>0.30</td>
<td>1.30</td>
<td>1</td>
</tr>
<tr>
<td>Method of reduction</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Pneumatic</td>
<td>–</td>
<td>–</td>
<td>0</td>
</tr>
<tr>
<td>Hydrostatic</td>
<td>0.29</td>
<td>1.26</td>
<td>1</td>
</tr>
</tbody>
</table>

Discussion

Intussusception is a common disease in infants and children around the world. The method of diagnosis and management of intussusception have developed over time. Investigations for the diagnosis of intussusception have gradually changed from intraoperative diagnosis and contrast enema to ultrasonography. The management also developed from primary surgery to nonsurgical reduction if there were no contraindications. Nonsurgical reduction has also varied in the techniques. The development of hydrostatic and pneumatic reduction techniques under radiologic guidance

Figure 1 The ROC curve of failure nonoperative reduction of intussusceptions predicted by risk scoring scheme (curved line) and a 50% chance prediction (diagonal line). Notes: Area under the ROC curve = 0.8068; 95% Confidence Interval = 0.7390–0.8762.

Abbreviation: ROC, receiver operating characteristic.
(ultrasonography or fluoroscopy) has still been reported. The decision for the method of diagnosis and treatment was dependent on patient characteristics, experience of patient care team (surgeons, radiologists, and pediatricians), facilities, and equipment.

In 2013, Jiang et al. collected the published data of intussusception in seven geographic regions of the world. He reported that the diagnosis of intussusception was mostly found by ultrasound in Central and South America, contrast enema in Eastern Mediterranean, and surgery in Africa. For the management, primary treatment was air or barium enema except in Africa and Central and South America where surgery was the primary treatment.

In our study, nonsurgical reduction was attempted if there were no contraindications with a success rate of 55.3%. We studied the prognostic indicators for failed reduction and found ten parameters in our earlier study. There were a few earlier reports about predictors in the literature. In 2016, Ntoulia et al. reported that the ultrasound findings of a distal mass and observation of the dissecting sign were the predictors for failed reduction. In 2015, Wong et al. found a palpable abdominal mass to be a risk factor. In 2014, He et al. found that the presence of bloody stool, free peritoneal fluid, trapped fluid in the intussusception, and location in the left side of the abdomen were associated with a lower success rate. Our study found that the predictors included the clinical signs and symptoms along with the ultrasound findings and mode of reduction.

From the earlier reviews, there were some scoring systems. In 1986, Guo et al. reported a large series of intussusception treated with air pressure enema. In that study, he proposed a clinical criteria scoring system as a guide in the determination of initial treatment. The parameters in that scoring system were the clinical signs and symptoms. In 2011, Weihmiller et al. set up the clinical criteria for the diagnosis of intussusception with a decision tree. His criteria, however, did not indicate a clinical prediction for failed reduction. In our study, we set up clinical prediction rules for predicting the failure of nonsurgical reduction of intussusception. We used the parameters from demography (body weight), symptoms (duration of symptoms, vomiting, rectal bleeding, and abdominal distension), signs (body temperature, palpable mass, and location of the mass), sonographic findings, and the method of reduction to calculate the scores.

The prediction of the nonsurgical reduction results might help the physician to communicate with the parents about the importance of attempting a nonsurgical reduction and prognosis of the patient. In some areas with no facilities for reduction, surgery was the treatment. The prediction scores may be used to facilitate the referral of cases to the center in which nonsurgical reduction could be performed. However, this study was a retrospective study that was one of our limitations. The validation of this prediction score should be performed before its actual use.

## Conclusion

These scoring guidelines were used to predict the results of nonoperative reduction and forecast the prognosis of the failed reduction. The usefulness of these prediction scores was to inform the parents before the reduction. These scores can be used as a guide to promote the referral of the cases to tertiary centers with facilities for nonoperative reduction if possible. Nevertheless, contraindications preventing nonoperative reduction still remain such as peritonitis, free air in abdominal X-ray, and nonresponsive shock. Validation for these scores is planned for the next study.

## Disclosure

The authors report no conflicts of interest in this work.

## References


