The American Journal of Surgery 220 (2020) 208–213

Contents lists available at ScienceDirect

The American Journal of Surgery

journal homepage: www.americanjournalofsurgery.com

The significance of abdominal radiographs with paucity of gas in pediatric adhesive small bowel obstruction

Brittany L. Johnson [a], Giovanni A. Campagna [b], Jonathan M. Hyak [b], Adam M. Vogel [a], Sara C. Fallon [a], Sohail R. Shah [a], Mary L. Brandt [a], Bindi J. Naik-Mathuria [a, *]

[a] Department of Pediatric Surgery, Texas Children's Hospital, 6701 Fannin Street, #1210, Houston, TX, 77030, USA
[b] Baylor College of Medicine, 1 Baylor Plaza, Houston, TX, 7730, USA

ARTICLE INFO

Article history:
Received 1 May 2019
Received in revised form
7 October 2019
Accepted 15 October 2019

Keywords:
Adhesive small bowel obstruction
Paucity of gas
Abdominal radiograph
Closed loop obstruction

ABSTRACT

Purpose: Management of children with adhesive small bowel obstruction (ASBO) is often based on abdominal radiographs (AXR). Our purpose was to determine the significance of paucity of gas on initial AXR.

Methods: Retrospective, single center review of children with ASBO between 2011 and 2015. Analysis included chi-square, non-parametric tests and multivariate regression.

Results: Of 207 cases, 99 were operative. Initial AXR showed paucity of gas in 41% and gaseous loops in 59%. Paucity was more common in operative patients (49% vs. 32%, $p = 0.01$). At operation, 71% of patients with paucity had closed loop or high-grade obstruction, compared to 29% of patients with gaseous loops ($p = <0.001$).

Conclusion: For children with ASBO with paucity of gas on AXR, complicated obstruction (closed loop or high-grade) should be considered. In children with high clinical suspicion of complicated obstruction, additional imaging with CT or SBFT may clarify the clinical picture.

Introduction

Adhesive small bowel obstruction (ASBO) is a common presentation in pediatric surgery, but optimal management continues to be debated. Most pediatric surgeons will attempt a trial of non-operative management unless there are signs of bowel ischemia or perforation at presentation.[1,2] The success rate of non-operative management for ASBO in children is reported as 16–63%, which is lower than in adults at 70–90%.[3,4] However, there are legitimate reasons to avoid operation in children given their shorter bowel length, which if resected unnecessarily could put them at risk for short gut syndrome. Their life span is also longer, placing them at increased risk of future adhesive obstructive episodes.

The decision to proceed with non-operative management is made based on clinical presentation and initial imaging obtained on admission. In children, this imaging is most commonly in the form of an abdominal radiograph (AXR), avoiding the exposure of children to radiation with a computed tomography (CT) scan. In many patients, serial AXR remains the only imaging modality used for clinical decision-making regarding whether and when operative intervention is required. This practice varies from that in adults, in whom CT is very commonly utilized for initial evaluation of ASBO.[4,5] Since the diagnostic sensitivity of ASBO is low using AXR alone, there is the potential to misdiagnose the severity of the obstruction.[5] In patients with dilated gaseous loops of small bowel with air/fluid levels and little or no colonic gas, the diagnosis of ASBO may be clear. In other cases, a portion or even the majority of the AXR may present with a paucity of gas containing no visibly dilated gaseous loops of bowel because the loops are filled only with fluid. This may cause the surgeon to assume a reduced severity of obstruction or misdiagnose the patient completely. Closed loop obstruction (also known as segmental volvulus) and high-grade obstruction are unlikely to resolve without operation, and early recognition is important to avoid complications of bowel ischemia. We hypothesized that these diagnoses are more common in patients with an initial AXR showing paucity of gas.

The purpose of this study is to evaluate the significance of

* Corresponding author.
E-mail addresses: bxjohns7@texaschildrens.org (B.L. Johnson), Giovanni.campagna@bcm.edu (G.A. Campagna), jonathan.hyak@bcm.edu (J.M. Hyak), amvogel@yexaschildrens.org (A.M. Vogel), scfallon@texaschildrens.org (S.C. Fallon), srshah2@texaschildrens.org (S.R. Shah), mlbrandt@texaschildrens.org (M.L. Brandt), bjnaikma@texaschildrens.org (B.J. Naik-Mathuria).

https://doi.org/10.1016/j.amjsurg.2019.10.035
0002-9610/

paucity of gas on initial abdominal radiograph for small bowel obstruction in the pediatric population.

Materials and methods

Patient selection and study design

This study was approved by Baylor College of Medicine's Institutional Review Board, Houston, Texas (H-44695). The medical records of all children presenting to an urban, tertiary referral hospital with an episode of ASBO between January 2011 and December 2015 were retrospectively reviewed. Cases were determined using International Classification of Disease, 9th and 10th Revision, Clinical Modifications (ICD-9, ICD-10) codes; small bowel obstruction (560.9, K56.69), small bowel obstruction due to adhesions (560.81, K 56.5), small bowel obstruction due to postoperative adhesions (560.81, K56.5), small bowel obstruction, partial (560.9, K56.69), small bowel perforation (569.83, K63.1), small bowel perforation, intraoperative (998.2, K91.72), unspecified intestinal obstruction (560.9, K56.60) and encounter for small bowel obstruction (49.89, Z76.89).

Inclusion criteria were ages 0–18 years and prior abdominal or pelvic surgery that was at least four weeks prior to development of obstruction. Exclusion criteria were non-adhesive bowel obstruction such as initial obstructive episode, congenital obstruction such as midgut volvulus or intestinal atresia, obstruction due to incarcerated hernia, complex medical diagnoses such as underlying genetic or metabolic diagnoses, and lack of AXR at presentation for ASBO.

Records of patients meeting inclusion criteria were reviewed for age at presentation, gender, number of prior episodes of ASBO, imaging obtained (AXR, (CT) and small bowel follow through (SBFT)), result of imaging, time to operative intervention, operative findings, incidence of bowel resection, and length of bowel resection.

Initial AXR images were classified as either paucity of gas (Fig. 1) or dilated, gaseous loops (Fig. 2) independently by two surgeon reviewers. Paucity of gas had to persist on the first AXR following decompression via a nasogastric tube in order to remain within this classification. Evaluations were made without knowledge of the type of obstruction diagnosed by a radiologist or at operation.

Patients were classified by the following management types: urgent operation, non-urgent operation, and non-operative management. Urgent operation was defined as patients who were taken to the operating room (OR) from the emergency department due to presenting signs of peritonitis on exam and/or clinical concern for bowel ischemia. Non-urgent operation patients failed a trial of non-operative management and were taken to the OR for change in clinical status or concerning imaging findings. Patients whose bowel obstruction resolved without operative intervention were classified into the non-operative management group.

Statistical analysis

Descriptive statistics were used to describe demographic data. Demographics and outcomes were described as medians for quantitative variables and numbers for categorical variables. Chi square and Fisher's exact tests were used to compare categorical variables. Statistical significance was defined as a $p < 0.05$. Logistic regression was used to evaluate clinical factors felt to be predictive of bowel resection. These factors were included in a multivariate model. All statistics were performed using IBM SPSS statistical software package version 25 (IBM Corporation, Armonk, NY).

Results

Of 207 cases of ASBO, 108 (52%) were successfully managed non-operatively, 35 (17%) required urgent operation, and 64 (31%) required non-urgent operation after failing a trial of non-operative management (NOM) (Fig. 3). Median age for all patients was 7 years (range: 6 months–18 years) and 56% were male. Multiple, dilated, gaseous bowel loops (classic for ASBO) were seen in 59% (123/207) and paucity of gas in 41% (84/207). Patients in the two AXR groups were similar in age (Dilated gaseous loops: 6 years (range: 6 months–18 years) vs Paucity of gas: 5 years (range: 6 months–18 years); $p = 0.4$). They also had similar incidence of prior operative ASBO (dilated gaseous loops: 20% vs paucity of gas: 15%, $p = 0.95$). Need for urgent operation, non-urgent operation and successful NOM were also similar among the groups (Fig. 3).

When initial AXR findings were compared to operative findings, we focused on closed loop obstruction (CLO) and high-grade obstruction (HGO) as these are the types of obstruction that rarely resolve without operation and have the highest risk of bowel loss. The accuracy of AXR compared to CT in diagnosing type of obstruction can be seen in Graph 1. When the high-risk conditions were combined, almost three-quarters (71%, 35/49) of patients with paucity of gas AXR had either CLO or HGO, compared to 29% (15/50) of patients with dilated gaseous loops AXR ($p < 0.001$). In the following sections, we describe the management of patients who initially presented with AXR with dilated loops of bowel and those with paucity of gas.

i. Initial AXR with dilated loops of bowel

There were 123 patients who presented with an initial AXR that showed dilated loops of bowel. Sixteen percent (20/123) of these were taken urgently to the OR. Prior to operation 25% (5/20) were evaluated with a CT scan. At operation, 20% were diagnosed with a closed loop obstruction with 100% of them requiring bowel resection. High grade obstruction was diagnosed in 30% with 33% (2/6) requiring bowel resection.

Twenty four percent (30/123) were taken to the OR after a trial of NOM. CT scan was obtained in 23% (7/30) of these patients. At operation, 7% were diagnosed with a closed loop obstruction with 100% requiring bowel resection. Ten percent were diagnosed with a high grade obstruction with 100% requiring bowel resection. Non-operative management was successful in 59% of patients who presented with dilated loops of bowel on initial AXR.

ii. Initial AXR with paucity of gas

There were 84 patients who presented with an initial paucity of gas on AXR. Eighteen percent (15/84) required urgent operation with 40% (6/15) of those being evaluated with a CT scan. Closed loop obstruction was diagnosed in 73% of these patients at operation and high grade obstruction diagnosed in 20%. Bowel resection was required in 27% (3/11) of closed loop obstruction patients and none of high grade obstruction patients.

Forty percent (34/84) of paucity of gas patients were given a trial of NOM and went on to require operative intervention. 59% of these patients were additionally evaluated with a CT scan. At operation, closed loop obstruction was diagnosed in 21% and high grade obstruction in 41%. Bowel resection was required in 57% (4/7) of closed loop obstruction and 43% (6/14) of high grade obstruction patients.

iii. Additional imaging

Overall, additional imaging was obtained in 47% (47/99) of the

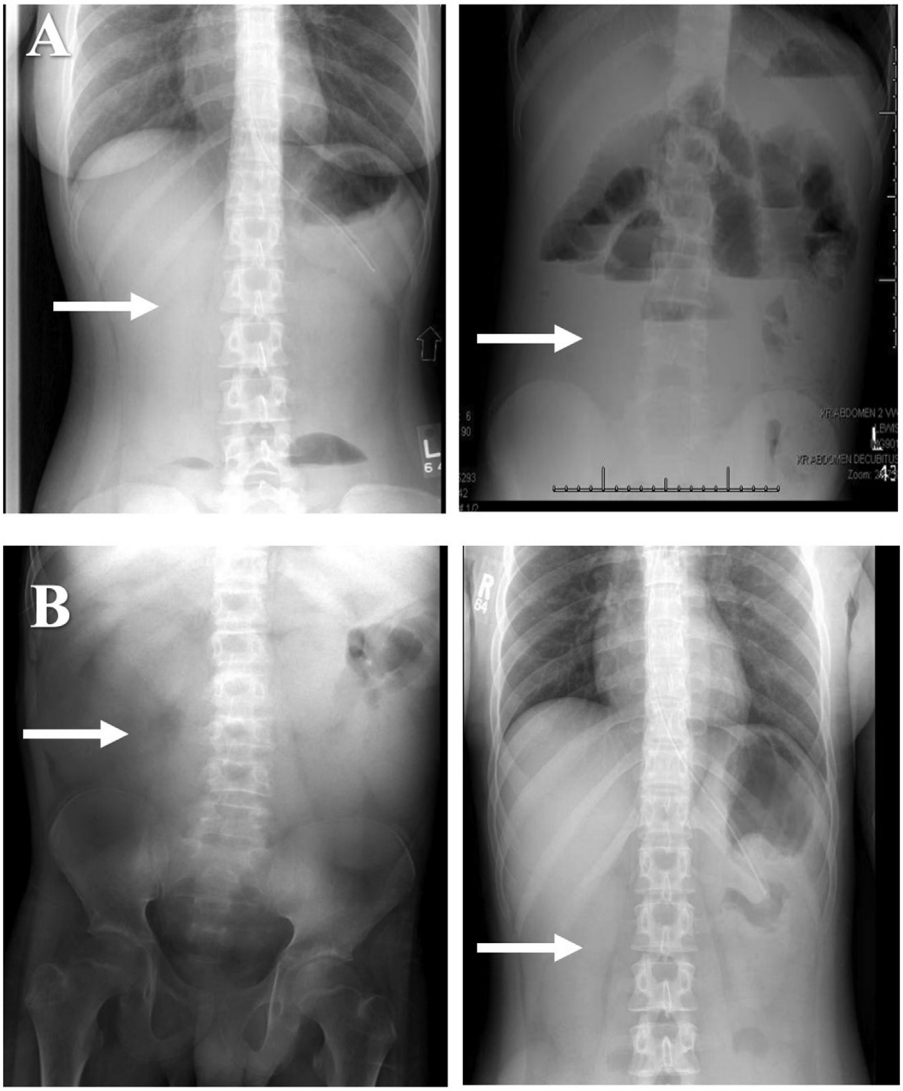


Fig. 1. Two patients with paucity of gas AXR (supine and upright films). Arrows point to the areas of the radiographs where paucity of gas was noted.

patients who required operation, and was more commonly obtained in those with initial paucity of gas AXR (paucity of gas 66% vs dilated gaseous loops 33%, $p = 0.002$). CT was the most prevalent imaging modality (87% (26/30)) vs SBFT 13% (5/30). For *all* patients, CT was significantly more accurate than AXR at diagnosing CLO (CT (23%) vs AXR 0%), $p < 0.001$, but HGO was similar (69% vs 66%). In patients with paucity of gas AXR in particular, CT was very accurate at diagnosing CLO compared to AXR alone (90% vs 0%, $p = <0.0001$), but the accuracy of HGO was actually slightly higher for AXR (Graph 1).

In patients who presented with paucity of gas AXR and were evaluated with serial AXR only (23 patients), incidence of bowel resection was 39% and median bowel loss was 43 cm. In the 26 patients who had further evaluation with CT scan, incidence of bowel resection was 30% and median bowel length loss was 14 cm, which was significantly shorter (AXR only: 43 cm vs. AXR + CT: 14 cm, $p = <0.001$). Since clinical findings are paramount in the evaluation and management of bowel obstruction, we performed a multivariate regression analysis adjusting for age, fever and leukocytosis at presentation. Following regression, the difference in bowel length loss was no longer significant [(Age: odds ratio (OR) 0.99, 95% confidence interval (CI) 0.89–1.12; $p = 0.98$); (Fever: OR 0.33, 95% CI 0.03–4.2; $p = 0.4$); (Leukocytosis: OR 1.33, 95% CI 0.32–1.02; $p = 0.7$)].

Discussion

Optimal management of pediatric adhesive small bowel obstruction with regards to the modality and timing of diagnostic imaging continues to be debated and appropriate timing to operation remains unclear.[6] Studies in pediatric ASBO have failed to identify clinical predictors such as leukocytosis, tachycardia, and fever that predict need for operation.[1–3,7] We sought to investigate the predictive nature of the initial abdominal radiograph in identifying patients who may benefit from earlier operative intervention.

Similar to published pediatric studies, most of our patients were evaluated with only an abdominal radiograph (AXR) during admission.[1–3] However, not all AXR are classic for ASBO. The purpose of this study was to analyze the significance of paucity of gas AXR. Since some of the bowel loops are not visible, they may represent a higher severity obstruction or closed loop obstruction. They may also be confused for severe constipation, a common diagnosis in children. Our results prove the hypothesis that paucity

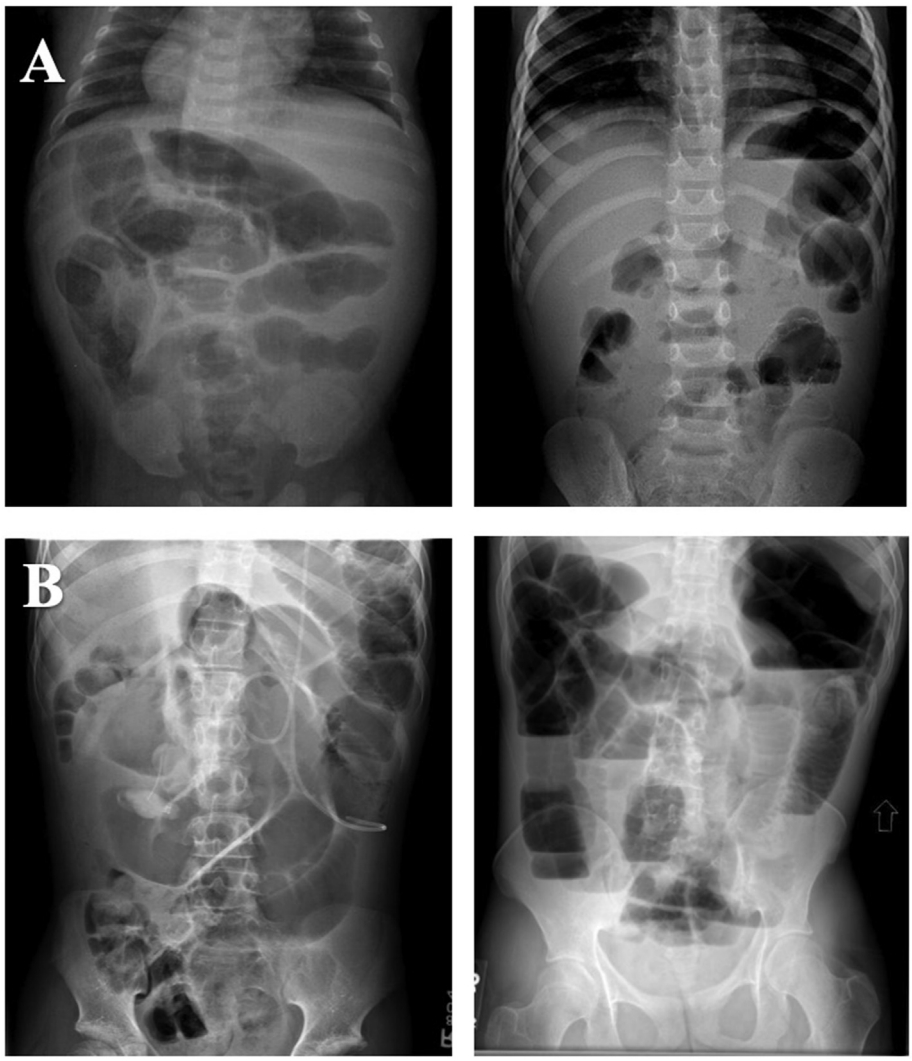


Fig. 2. Two patients with dilated loops of bowel on AXR (supine and upright films).

of gas AXR has a higher association with high-grade or closed loop obstruction than dilated gaseous loops AXR. Based on these data, we are recommending that children with a high clinical suspicion of a bowel obstruction and paucity of gas on initial AXR should receive additional imaging with CT scan or a small-bowel contrast study to clarify the diagnosis and avoid delaying definitive treatment of complicated bowel obstruction. This is not the population that should be observed with serial AXR only, as they may be at much higher risk of bowel ischemia and the AXR will not show resolution of dilated gaseous loops. The evidence supports the higher accuracy of CT over AXR for the diagnosis of SBO[8–10]; additionally, we showed that it is particularly more accurate for diagnosing closed loop obstruction, especially in patients with paucity of gas AXR. In addition, in patients with paucity of gas AXR we found that earlier CT was associated with faster time to the operating room, which suggests that CT helped to clarify the diagnosis and determine the patients that needed surgery.

We previously reported from this same group of patients that as time to operation increases, the incidence of bowel resection increases, most significantly after 48 h of non-operative management.[11] Therefore, even in patients with dilated, gaseous loops AXR, we recommend an additional imaging modality (CT or SBFT) in when there is lack of clinical improvement within 48 h of non-operative management.

Patients who were successfully managed non-operatively had lower incidence of paucity of gas on initial AXR. This suggests that these patients did not have a high grade or closed loop obstruction as these obstructions do not resolve without operative intervention. The majority of these patients had further imaging to clarify the diagnosis shortly after initial AXR in order to safely continue non-operative management.

While we found that patients with an initial paucity of gas AXR and no additional imaging had more bowel length loss than those with additional imaging, this did not hold true on multivariate regression when adjusting for clinical factors at presentation that may have indicated bowel ischemia at presentation. Given the small sample size, these results are likely underpowered for this type of analysis and highlights the need for prospective investigation.

Since very few patients received a small bowel follow-through contrast study, this modality was not a focus of our analysis. However, given recent reports of successful resolution of SBO using gastrografin studies[12,13], we plan to incorporate this into our future clinical algorithms.

There were several limitations to our study. This was a retrospective review, thus we were limited by a lack of documentation on type and location of obstruction from radiology on imaging and by the operating surgeon. Given the retrospective nature of this

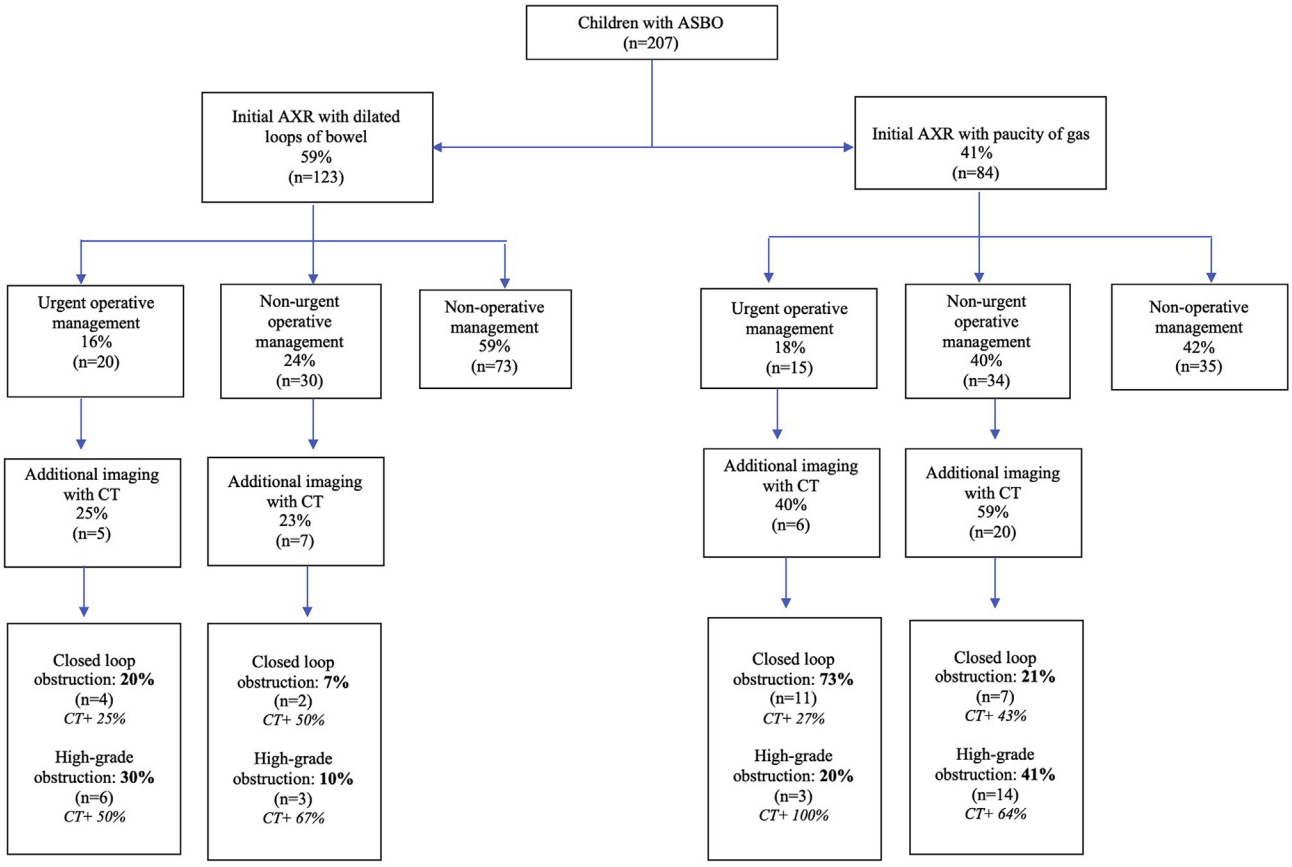
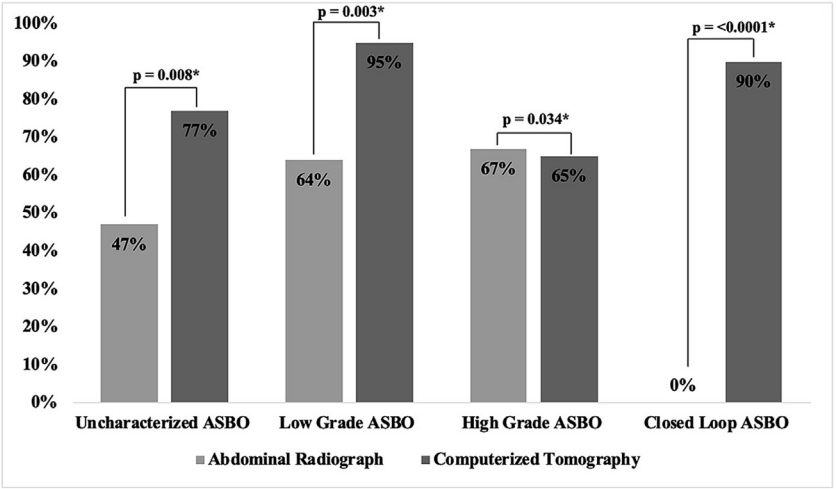


Fig. 3. Management of patients per initial AXR.



Graph 1. Accuracy of AXR vs. CT scan for diagnosing type of obstruction in patients with paucity of gas on initial AXR.

study, it is difficult to ascertain the clinical decision making that was involved in these patients. Another limitation is a lack of consistency amongst radiologists and surgeons on their criteria for diagnosing a low-grade, high-grade, or closed loop obstruction. Finally, the small sample size, which may limit the generalizability of our results.

Conclusion

In children with a clinical picture of adhesive small bowel obstruction whose initial abdominal radiograph shows paucity of gas, high-grade or closed loop obstruction should be considered. In these cases, an additional imaging modality such as CT scan may aid in clarifying the diagnosis and identifying patients who may benefit

from timely operation.

Author contributions

BN and BJ conceptualized the project and were responsible for study design. BJ, JH, and GC were responsible for chart review. BJ analyzed the raw data. BJ prepared the manuscript and revised it according to feedback provided by BN, who was involved in critical revisions and provided important intellectual content. All authors approved the final manuscript.

Funding source

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

No authors have disclosed any financial interests, arrangements, or affiliations associated with this work.

References

1. Lautz TB, Barsness KA, et al. Adhesive small bowel obstruction-acute management and treatment in children. *Semin Pediart Surg*. 2014;23:349–352.
2. Lautz TB, Raval MV, et al. Adhesive small bowel obstruction in children and adolescents: operative utilization and factors associated with bowel loss. *J Am Coll Surg*. 2011;212:855–861.
3. Feign E, Kravarusic D, Goldrat I, et al. The 16 golden hours for conservative treatment in children with postoperative small bowel obstruction. *J Pediatr Surg*. 2010;45:966–968.
4. Becker BA, Lahham S, Gonzales MA, et al. A prosepctive, multicenter evaluation of point-of-care ultrasound for small bowel obstruction in the emergeny department. *Acad Emerg Med*. 2019;26(8):921–930.
5. Maglinte DD, Balthazar EJ, Kelvin FM, et al. The role of radiology in the diagnosis of small bowel obstruction. *AJR*. 1997;168:1171–1180.
6. Eeson GA, Wales P, et al. Adhesive small bowel obstruction in children: should we still operate? *J Pediatr Surg*. 2010;45:969–974.
7. Akgur FM, Tanyel FC, et al. Adhesive small bowel obstruction in children: the place and predictors of success for conservative treatment. *J Pediatr Surg*. 1991;26, 37-4.
8. Qiuyan W, Govind B, et al. Utility of CT in the diagnosis and management of small-bowel obstruction in children. *Pediatr Radiol*. 2012;42:1441–1448.
9. Silva AC, Pimenta M, Guimaraes LS. Small bowel obstruction: what to look for. *RadioGraphics*. 2009;29:423–439.
10. Jabra AA, Eng J, et al. CT of small bowel obstruction in children: sensitivity and Specificity. *AJR*. 2001;177:431–436.
11. Hyak J, Campagna G, Johnson B, et al. Management of pediatric adhesive small bowel obstruction: do timing of surgery and age matter? *J Surg Res*. 2019;243:384–390.
12. Linden AF, Raiji MT, Kohler JE, et al. Evaluation of water-soluble contrast protocol for nonoperative management of pediatric adhesive small bowel obstruction. *J Pediatr Surg*. 2018;54(1):184–188.
13. Lee C, Hung M, Lin L, et al. Evaluation of a water-soluble contrast agent for the conservative management of adhesive small bowel obstruction in pediatric patients. *J Pediatr Surg*. 2015:581–585.