Outcomes of a low-osmolar water-soluble contrast pathway in small bowel obstruction

Heather G. Lyu, MD, Manuel Castillo-Angeles, MD, MPH, Melanie Bruno, Zara Cooper, MD, Deepika Nehra, MD, Stephanie L. Nitzschke, MD, Reza Askari, MD, Edward Kelly, MD, Naomi Shimizu, MD, Robert Riviello, MD, MPH, Ali Salim, MD, *and* **Joaquim M. Havens, MD***, Boston, Massachusetts*

AAST Continuing Medical Education Article

Accreditation Statement

This activity has been planned and implemented in accordance with the Essential Areas and Policies of the Accreditation Council for Continuing Medical Education through the joint providership of the American College of Surgeons and the American Association for the Surgery of Trauma. The American College Surgeons is accredited by the ACCME to provide continuing medical education for physicians.

AMA PRA Category 1 Credits™

The American College of Surgeons designates this journal-based CME activity for a maximum of 1 AMA PRA Category 1 Credit™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Of the AMA PRA Category 1 Credit™ listed above, a maximum of 1 credit meets the requirements for self-assessment.

Credits can only be claimed online

American College of Surgeons
Inspiring Quality:
Highest Standards, Better Outcomes

100+*years*

Objectives

After reading the featured articles published in the *Journal of Trauma and Acute Care Surgery*, participants should be able to demonstrate increased understanding of the material specific to the article. Objectives for each article are featured at the beginning of each article and online. Test questions are at the end of the article, with a critique and specific location in the article referencing the question topic.

Claiming Credit

To claim credit, please visit the AAST website at http://www.aast.org/ and click on the "e-Learning/MOC" tab. You must read the article, successfully complete the post-test and evaluation. Your CME certificate will be available immediately upon receiving a passing score of 75% or higher on the post-test. Post-tests receiving a score of below 75% will require a retake of the test to receive credit.

Disclosure Information

In accordance with the ACCME Accreditation Criteria, the American College of Surgeons, as the accredited provider of this journal activity, must ensure that anyone in a position to control the content of J Trauma Acute Care Surg articles selected for CME credit has disclosed all relevant financial relationships with any commercial interest. Disclosure forms are completed by the editorial staff, associate editors, reviewers, and all authors. The ACCME defines a `commercial interest' as "any entity producing, marketing, re-selling, or distributing health care goods or services consumed by, or used on, patients." "Relevant" financial relationships are those (in any amount) that may create a conflict of interest and occur within the 12'months preceding and during the time that the individual is engaged in writing the article. All reported conflicts are thoroughly managed in order to ensure any potential bias within the content is eliminated. However, if you'perceive a bias within the article, please report the circumstances on the evaluation form.

Please note we have advised the authors that it is their responsibility to disclose within the article if they are describing the use of a device, product, or drug that is not FDA approved or the off-label use of an approved device, product, or drug or unapproved usage.

Disclosures of Significant Relationships with Relevant Commercial Companies/Organizations by the Editorial Staff

Ernest E. Moore, Editor: PI, research support and shared U.S. patents Haemonetics; PI, research support, Instrumentation Laboratory, Inc.; Co-founder, Thrombo Therapeutics. Associate Editors David Hoyt, Ronald V. Maier and Steven Shackford have nothing to disclose. Editorial staff and Angela Sauaia have nothing to disclose.

Author Disclosures

Joaquim Havens - Johnson & Johnson - Grant.

Reviewer Disclosures

The reviewers have nothing to disclose.

Cost

For AAST members and Journal of Trauma and Acute Care Surgery subscribers there is no charge to participate in this activity. For those who are not a member or subscriber, the cost for each credit is $25.

System Requirements

The system requirements are as follows: Adobe® Reader 7.0 or above installed; Internet Explorer® 7 and above; Firefox® 3.0 and above, Chrome® 8.0 and above, or Safari™ 4.0 and above.

Questions

If you have any questions, please contact AAST at 800-789-4006. Paper test and evaluations will not be accepted.

BACKGROUND: Adhesive small-bowel obstruction (SBO) is a common surgical condition accounting for a significant proportion of acute surgical admissions and surgeries. The implementation of a high-osmolar water-soluble contrast challenge has repeatedly been shown to reduce hospital length of stay and possibly the need for surgery in SBO patients. The effect of low-osmolar water-soluble contrast challenge however, is unclear. The aim of this study is to evaluate the outcomes of an SBO pathway including a low-osmolar water-soluble contrast challenge.

METHODS: A prospective cohort of patients admitted for SBO were placed on an evidence-based SBO pathway including low-osmolar water-soluble contrast between January 2017 and October 2018 and were compared with a historical cohort of patients prior to the implementation of the pathway from September 2013 through December 2014. The primary outcome was length of stay less than 4 days with a secondary outcome of failure of nonoperative management.

RESULTS: There were 140 patients enrolled in the SBO pathway during the study period and 101 historic controls. The SBO pathway was independently associated with a length of stay less than 4 days (odds ratio, 1.76; 95% confidence interval, 1.03–3.00). Median length of stay for patients that were successfully managed nonoperatively was lower in the SBO pathway cohort compared with controls (3 days vs. 4 days, $p = 0.04$). Rates of readmission, surgery, and bowel resection were not significantly different between the two cohorts.

CONCLUSION: Implementation of an SBO pathway using a low-osmolarity contrast is associated with decreased hospital length of stay. Rates of readmission, surgery, and need for bowel resection for those undergoing surgery were unchanged. An SBO pathway utilizing low-osmolarity water-soluble contrast is safe and effective in reducing length of stay in the nonoperative management of adhesive small-bowel obstructions. (*J Trauma Acute Care Surg.* 2019;87: 630–635. Copyright © 2019 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic study, level IV.

KEY WORDS: Small-bowel obstruction; omnipaque; water-soluble contrast challenge.

Adhesive small-bowel obstruction (SBO) is a significant problem for surgeons and patients alike, accounting for more than 300,000 hospitalizations and costing 1.3 billion dollars annually.[1,2] Despite the fact that SBO is the most common complication after abdominal surgery, treatments for SBO are variable and unstandardized.[3] Patients with concern for bowel compromise must undergo immediate operative intervention. However, there is no widespread consensus on the nonoperative management for patients who do not need emergency surgery.

Nonoperative management is typically comprised of nasogastric tube (NGT) decompression, bowel rest, and hydration with intravenous fluids. While nonoperative management with NGT decompression can decrease rates of unnecessary surgery and associated complications for patients with SBO, there is a risk of a delayed operation and poor outcomes for patients with unresolving obstruction. Both Bologna and Eastern Association for the Surgery of Trauma guidelines demonstrate the importance of limiting nonoperative management for SBO to 3 to 5 days.[4,5] They both cite a nonoperative treatment option recommended by the World Society of Emergency Surgery which includes the administration of a high-osmolar, water-soluble contrast (Gastrografin) through the NGT called the water-soluble contrast challenge (WSCC).[6,7] Passage of the contrast to the colon on follow up abdominal X-rays is associated with successful nonoperative management.[4] Several studies have demonstrated its utility in increasing the identification of patients who would benefit from surgery, reducing operative intervention, and hospital length of stay (LOS).[1,8] It has been suggested that it is the high-osmolarity component of Gastrografin that offers both a diagnostic and therapeutic benefit.[7] While the administration of Gastrografin has been proven to be safe and effective as nonoperative management of adhesive SBO, alternatives including low osmolar water-soluble contrasts have been minimally explored.[9]

There are several benefits to using low osmolar water-soluble contrast over its high osmolar counterparts. Gastrografin has been known to cause significant pulmonary edema on aspiration and for patients with high aspiration risk, Omnipaque is typically recommended over Gastrografin as it causes a relatively decreased inflammatory response in the lungs.[10] The American College of Radiology also recommends low osmolar contrast for patients with suspected high grade obstructions due to increased aspiration risk.[11] Despite these previously reported benefits of Omnipaque, there have been limited studies in its utilization in the management of adhesive SBOs.

With the goal of standardizing care and improving adherence to evidence-based best practices, we developed an evidence-based SBO pathway which included a WSCC using the low-osmolar water-soluble contrast Omnipaque. The aim of this study was to determine the efficacy of an SBO pathway using Ominpaque. We hypothesized that the use of the new pathway would reduce LOS, but not need for surgery, without increasing complications or readmissions, in patients with adhesive SBO.

METHODS

The Pathway

The SBO pathway was implemented at a single academic institution. All patients above the age of 18 admitted for adhesive SBO to the emergency general surgery service after April 2015 were placed on the SBO pathway. Pregnant patients, patients with active cancer or evidence of a malignant bowel obstruction, and those with an intraabdominal infection were excluded from the SBO pathway. Patients with concern for bowel ischemia, abdominal sepsis, or with peritonitis underwent urgent or emergent surgical exploration and were excluded from the pathway. All patients on the SBO pathway underwent at least 2 hours of NGT decompression prior to administration of 100 mL of undiluted

Submitted: April 29, 2019, Revised: May 23, 2019, Accepted: May 26, 2019, Published online: June 12, 2019.

From the Division of Trauma, Burns, Surgical Critical Care and Emergency General Surgery, Brigham and Women's Hospital, Boston, Massachusetts (H.G.L., M.C-A., M.B., Z.C., D.N., S.L.N., R.A., E.K., N.S., R.R., A.S., J.M.H.).

Address for reprints: Heather Lyu, MD, Department of Surgery, 75 Francis St, Boston, MA 02115; email: hlyu@bwh.harvard.edu.

DOI: 10.1097/TA.0000000000002401

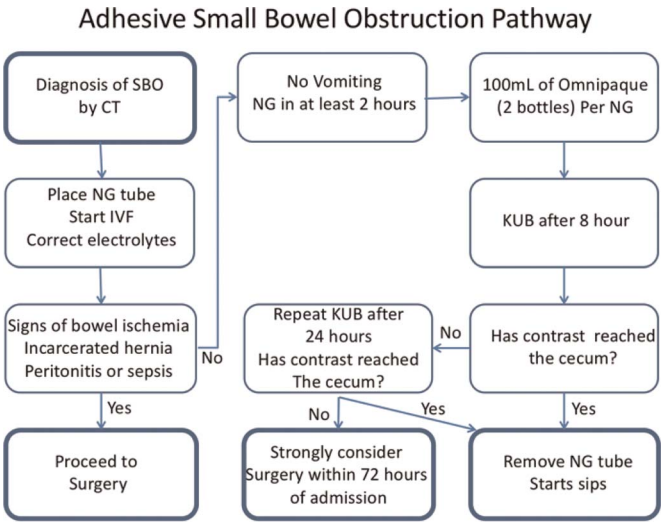

Figure 1. Adhesive SBO pathway.

Omnipaque. An abdominal x-ray was performed 8 hours after administration of Omnipaque and repeated at 24 hours if there was no passage of contrast to the cecum. If there was no passage of contrast at the second x-ray, patients were strongly considered for surgery (Fig. 1). However, timing for surgery was left up to the discretion of the surgeon.

Participants

Patients on the SBO pathway from January 2017 through October 2018 were prospectively followed and compared with a historical cohort of patients admitted for adhesive SBO prior to the implementation of the pathway from September 2013 through December 2014. Patients on the SBO pathway prior to January 2017 were excluded from the study to address high rates of noncompliance in the first year of pathway implementation. Similar to the exclusion criteria for the pathway, patients with concern for bowel ischemia, abdominal sepsis, or with peritonitis who underwent urgent or emergent surgical exploration, pregnant patients, patients with active cancer or evidence of a malignant bowel obstruction, and those with an intraabdominal infection were excluded from the study.

Variables and Outcome Measures

Demographic variables including age, sex, and race were collected. Other clinical variables including BMI, comorbidities, chief complaint, and vital signs on admission were collected. Our primary outcome was LOS. This variable was dichotomized to greater than or equal to 4 days vs. less than 4 days for the multivariate analysis. The decision to use this cutoff was based on the median hospital LOS for the entire cohort, which was 4 days. Secondary outcomes measured included in-hospital mortality, surgery, need for bowel resection, and 30-day readmission.

Statistical Analysis

Comparative univariate analyses were completed with Pearson's χ^2 test for categorical variables, analysis of variance test for continuous variables, and Kruskal-Wallis test for nonparametric continuous variables. Multivariate analysis was performed to identify independent risk factors for decreased hospital LOS for patients admitted with adhesive SBO. For the main outcome, logistic regression was performed using backward stepwise selection, with inclusion of variables with known clinical influence or that approached significance ($p \leq 0.10$) in univariate analysis. Statistical significance was set at a p value of less than 0.05. All statistical analyses were performed using STATA (StataCorp LP, Version 14.0, College Station, TX, USA). This study was approved by the Partners Institutional Review Board (IRB approval number 2017P001850).

RESULTS

A total of 140 patients were enrolled in the SBO pathway during the study period and included in the study. This group was compared with a historical cohort of 101 patients. There were more nonwhite patients in the pathway group. Patients in the pathway group were also more likely to be transfers from other hospitals than admissions from the emergency department. There were no other statistically significant differences in other demographic or clinical variables between the two groups (Table 1).

TABLE 1. Demographic Table

	Pre-SBO Pathway (n = 101)	Post-SBO Pathway (n = 140)	*p* Value
Age: median (IQR), y	62 (52–70)	66.5 (53–76)	0.0501
Race, n (%)			
White	89 (88.12)	91 (65.00)	<0.001
Black	9 (8.91)	25 (17.86)	
Asian	3 (2.97)	1 (0.71)	
Other	0	18 (12.86)	
Unknown	0	4 (2.86)	
Ethnicity, n (%)			0.302
Hispanic	9 (8.91)	17 (12.14)	
Non-Hispanic	91 (90.10)	115 (82.14)	
Sex, n (%)			
Male	44 (43.56)	68 (48.57)	0.628
Female	57 (56.44)	72 (51.43)	
BMI, median (IQR)	25 (22.9–30.6)	25 (21.9–29.1)	0.5741
CCI score, median (IQR)	4 (2–5)	4 (2–5)	0.75
Patient origin, n (%)			0.003
ED	83 (82.18)	89 (63.57)	
Other	0	4 (2.86)	
Transfer in	17 (16.83)	46 (32.86)	
Blank	1 (0.99)	1 (0.71)	
Chief complaint, n (%)			0.03
Abdominal pain/tenderness	88 (87.13)	126 (90.00)	
Nausea/vomiting	11 (10.89)	4 (2.86)	
Shortness of breath	0	2 (1.43)	
Other	2 (1.98)	6 (4.29)	
Pulse, median (IQR)	84 (74–98)	87 (77–98)	0.35
SBP, median (IQR)	137 (121–163)	136 (122–157)	0.96
Cr, median (IQR)	0.94 (0.72–1.17)	0.9 (0.77–1.2)	0.56
Glucose, median (IQR)	125 (106–149)	120 (107–149)	0.95
WBC, median (IQR)	10.66 (8.73–12.81)	9.9 (7.33–12.26)	0.10
INR, median (IQR)	1 (1–1.2)	1.1 (1–1.2)	0.10
Alb, median (IQR)	4.2 (3.9–4.6)	4.3 (3.9–4.65)	0.87

There were no differences in the number of patients requiring surgery between the two groups with 19.8% in the historical cohort and 17.9% of patients in the pathway group requiring surgical intervention. For patients who underwent surgical intervention, there was no difference in the number of small-bowel resections performed between the two groups. There were no differences between groups in mortality or readmission rate (Table 2).

There was no statistically significant difference in median hospital LOS between the two groups. Median hospital LOS was reduced after implementation of the pathway for patients who did not have surgery (3 days vs. 4 days, $p = 0.04$). There were significantly more patients whose LOS was less than 4 days in the pathway group (49.3% vs. 35.6%, $p = 0.035$). Enrollment in the pathway was independently associated with a hospital LOS less than 4 days in multivariate analysis, and this remained significant for the subset of patients who did not undergo surgery (Table 3).

DISCUSSION

In this study, we found that the utilization of a low-osmolar water-soluble contrast, Omnipaque, in an SBO treatment pathway is associated with decreased hospital LOS. Our results were consistent with previous findings by investigators in Wisconsin who found that patients placed on their SBO protocol using Omnipaque had decreased LOS as well as decreased rates of surgery.[9] While we did not see the same difference in rates of surgery between the two cohorts in our study, we had relatively low rates of surgery in the historical group compared to the rates of surgery cited in Trevino's study (19.8% vs. 38%).[9] Decreased rates of surgery in previous studies may not necessarily indicate therapeutic effect of the SBO pathway. High rates of surgery in the historical group in the Wisconsin study suggests that there may have been a cohort of patients that underwent unnecessary surgery. Their results indicate that the pathway may prevent unnecessary or negative surgeries through better identification of patients that can be managed nonoperatively.

Our findings confirm the well-studied benefits of a WSCC.[1,4,6–8] The major difference is in the osmolarity of the utilized contrast. Gastrografin, which has been the contrast of choice in previous studies as well as both Bologna and EAST guidelines for nonoperative management of SBO, is a high-osmolar water-soluble contrast and contains 10 g of sodium diatrizoate and 66 g of meglumine diatrozoate with an osmolarity of 1900 mmol/kg H_2O.[4,5,12] In contrast, Omnipaque has a significantly lower osmolarity of 660 mmol/kg H_2O.[13] Both Gastrografin and Omnipaque are commonly used in fluoroscopic gastrointestinal examinations,[14] however, Gastrografin has almost been exclusively studied for the treatment of adhesive SBOs. In many studies, Gastrografin has been shown to have therapeutic value for SBOs with faster resolution of SBOs and decreased hospital LOS.[15,16] The reduction in LOS is thought to be mainly due to the prognostic ability of Gastrografin and can likely be seen with the utilization of any radiopaque contrast. However, faster resolution of obstruction and the reduction in rates of surgery seen in some studies[7,17,18] may be secondary to the hyperosmolarity of Gastrografin facilitating fluid shifts from the bowel wall to the bowel lumen subsequently reducing edema and enhancing peristaltic activity.[15,19] Gastrografin has also been shown to resist colonic fluid absorption leading to stool softening.[14] However, studies have not consistently shown reductions in rate of operative intervention, and the potential impact of Gastrografin on similar clinical outcomes including rates of bowel resection and recurrence are controversial and less known.[20,21]

As previous studies have suggested, the utilization of any radiopaque contrast including Omnipaque, can contribute to the reduction in hospital LOS.[9] As previously mentioned, Omnipaque may be preferred over high osmolar contrasts in patients with suspected high-grade bowel obstruction or other high risk factors for aspiration.[10,11] Additionally, in a double-blind parallel

TABLE 2. Outcomes

	Pre-SBO Pathway (n = 101)	Post-SBO Pathway (n = 140)	*p* Value
LOS—all comers: median (IQR), d	4 (3–7)	4 (2–7)	0.1114
LOS—all comers, n (%)			0.035
> 4 d	65 (64.36)	71 (50.71)	
< 4 d	36 (35.64)	69 (49.29)	
LOS for patients who did NOT have surgery: median (IQR), d	4 (3–5), n = 81	3 (2–5), n = 115	0.0431
LOS—no surgery, n (%)			0.013
> 4 d	47 (58.02)	46 (40.00)	
< 4 d	34 (41.98)	69 (60.00)	
LOS for patients with surgery: median (IQR), d	11.5 (8–18.5), n = 20	11 (7–16), n = 25	0.7748
Surgery, n (%)	20 (19.80%)	25 (17.86%)	0.702
If surgery, bowel resections	6 (5.94%)	11 (7.86%)	0.566
Discharge disposition, n (%)			0.94
Home	91 (91.92)	121 (91.67)	
Non-home	8 (8.08)	11 (8.33)	
Mortality, n (%)	0	3 (2.14%)*	0.267
Readmission, n (%)	7 (6.93%)	10 (7.14%)	0.949

*The three mortalities in the post-SBO pathway cohort were: (1) patient with chronic respiratory insufficiency that died from hypercarbic respiratory failure 2 days after resolution of SBO, (2) patient with paraesophageal hernia that died from aspiration pneumonia in the postoperative setting, (3) patient with complex cardiac history that died from cardiac arrest in the postoperative setting.

TABLE 3. Independent Factors for Outcome: LOS < 4

	Variables	OR	95% CI	*p* Value
All Patients	SBO pathway	1.76	1.03–3.00	0.036
	Age	0.99	0.97–1.00	0.378
	Sex	0.93	0.55–1.57	0.806
	Variable	**OR**	**95% CI**	***p* value**
Patients who did not have surgery	SBO pathway	2.05	1.15–3.67	0.015
	Age	0.99	0.97–1.01	0.486
	Sex	0.96	0.54–1.70	0.891

OR, odds ratio; 95% CI, 95% confidence interval.

comparison of Gastrografin and Omnipaque, the low osmolar contrast was found to retain its radiographic density in the small bowel better than Gastrografin, likely due to decreased dilution by enteric fluids.[13] Other nonclinical benefits of Ominpaque must be considered when deciding among multiple contrast agents. At our institution, the decision to use Omnipaque was driven by lower cost and availability. Typically, Omnipaque is more affordable than Gastrografin which may lead to widespread availability of Omnipaque over other contrast agents.[14]

There are several limitations of our study. We used a retrospective sample of patients who were not on the SBO pathway which may introduce unintended bias. A randomized, controlled trial with three arms comparing patients with no contrast, Gastrografin, and Omnipaque would provide a more objective and comprehensive perspective of the true differences. Also, in both cohorts, enteral contrast administration for CT imaging was not factored into the analysis as this data were not completely available for study. Many patients receive enteral contrast with initial diagnostic imaging, and this could be a potential confounder. However, the practice of oral contrast administration for CT scans has not changed significantly over time, and the differences between the historical and the pathway cohorts in enteral contrast administration for diagnostic imaging are likely minimal. Also, enteral contrast used for CT scans is often diluted significantly and cannot be used or interpreted interchangeably with the Omnipaque as given in its concentrated form for the SBO pathway. Future studies may benefit from the inclusion of pre-pathway administration of enteral contrast in their analyses. Additionally, long-term outcomes including recurrence were not evaluated. We hypothesized that associations between Omnipaque utilization and long-term outcomes would be unlikely, as seen in previous studies. Nevertheless, future studies may benefit from inclusion of both acute and long-term metrics.

Our findings demonstrate that Omnipaque has the same predictive value as Gastrografin for adhesive SBOs, leading to reduced LOS. The lower concentration of Omnipaque may reduce the potential clinical impact of a contrast challenge as there were no differences in rates of surgery as seen in some studies using Gastrografin. Future prospective, randomized controlled studies to further delineate the benefits of Omnipaque, particularly in relation to Gastrografin, are warranted. Nevertheless, the treatment algorithm used in our study is safe and effective and may still deliver significant benefits for both patients and hospitals. Given the cost differences between the two contrast agents, a cost-benefit analysis is justified and underway.

CONCLUSION

This study shows that low osmolarity water-soluble contrasts are safe to use in management algorithms for SBOs and can reduce hospital LOS. Our findings demonstrate the diagnostic and predictive role of Omnipaque for patients with adhesive SBOs.

AUTHORSHIP

H.L., J.H. participated in the design. H.L., M.B., Z.C., D.N., S.N., R.A., E.K., N.S., R.R., A.S., J.H. participated in the data acquisition. H.L., M.C.A., J.H. participated in the analysis/interpretation of data. H.L., M.C.A., M.B., Z.C., D.N., S.N., R.A., E.K., N.S., R.R., A.S., J.H. participated in the drafting/revisions of article.

ACKNOWLEDGMENTS

H.L. is supported by the National Library of Medicine Institutional training grant for research training in biomedical informatics and data science (T15) under award number T15LM007092. There were no other funding sources.

DISCLOSURE

J.H. has a research grant from Johnson and Johnson. No Johnson and Johnson products were discussed in this article. For the remaining authors, no conflicts were declared.

REFERENCES

1. Azagury D, Liu RC, Morgan A, Spain DA. Small bowel obstruction: a practical step-by-step evidence-based approach to evaluation, decision making, and management. *J Trauma Acute Care Surg*. 2015;79(4):661–668.
2. Ray NF, Denton WG, Thamer M, Henderson SC, Perry S. Abdominal adhesiolysis: inpatient care and expenditures in the United States in 1994. *J Am Coll Surg*. 1998;186(1):1–9.
3. Baghdadi YM, Choudhry AJ, Goussous N, Khasawneh MA, Polites SF, Zielinski MD. Long-term outcomes of gastrografin in small bowel obstruction. *J Surg Res*. 2016;202(1):43–48.
4. Di Saverio S, Coccolini F, Galati M, et al. Bologna guidelines for diagnosis and management of adhesive small bowel obstruction (ASBO): 2013 update of the evidence-based guidelines from the world society of emergency surgery ASBO working group. *World J Emerg Surg*. 2013;8(1):42.
5. Maung AA, Johnson DC, Piper GL, et al. Evaluation and management of small-bowel obstruction: an Eastern Association for the Surgery of Trauma practice management guideline. *J Trauma Acute Care Surg*. 2012;73(5 Suppl 4):S362–S369.
6. Ceresoli M, Coccolini F, Montori G, Sartelli M, Catena F, Ansaloni L. Water-soluble contrast agent in adhesive small bowel obstruction: the game is still on. *Surgery*. 2017;162(1):199–200.

7. Ceresoli M, Coccolini F, Catena F, Montori G, Di Saverio S, Sartelli M, Ansaloni L. Water-soluble contrast agent in adhesive small bowel obstruction: a systematic review and meta-analysis of diagnostic and therapeutic value. *Am J Surg*. 2016;211(6):1114–1125.
8. Goussous N, Eiken PW, Bannon MP, Zielinski MD. Enhancement of a small bowel obstruction model using the gastrografin® challenge test. *J Gastrointest Surg*. 2013;17(1):110–116; discussion p.6–7.
9. Trevino CM, VandeWater T, Webb TP. Implementation of an adhesive small bowel obstruction protocol using low-osmolar water soluble contrast and the impact on patient outcomes. *Am J Surg*. 2018.
10. Morcos SK. Effects of radiographic contrast media on the lung. *Br J Radiol*. 2003;76:290–295.
11. American College of Radiology. ACR Appropriateness Criteria: Suspected Small Bowel Obstruction; 2013. https://acsearch.acr.org/docs/69476/Narrative/. Accessed April 24, 2019.
12. Choi HK, Chu KW, Law WL. Therapeutic value of gastrografin in adhesive small bowel obstruction after unsuccessful conservative treatment: a prospective randomized trial. *Ann Surg*. 2002;236(1):1–6.
13. Stordahl A, Laerum F, Gjølberg T, Enge I. Water-soluble contrast media in radiography of small bowel obstruction. Comparison of ionic and non-ionic contrast media. *Acta Radiol*. 1988;29(1):53–56.
14. Pollentine A, Ngan-Soo E, McCoubrie P. Acceptability of oral iodinated contrast media: a head-to-head comparison of four media. *Br J Radiol*. 2013;86(1025):20120636.
15. Assalia A, Schein M, Kopelman D, Hirshberg A, Hashmonai M. Therapeutic effect of oral gastrografin in adhesive, partial small-bowel obstruction: a prospective randomized trial. *Surgery*. 1994;115(4):433–437.
16. Abbas S, Bissett IP, Parry BR. Oral water soluble contrast for the management of adhesive small bowel obstruction. *Cochrane Database Syst Rev*. 2007;(3):CD004651.
17. Di Saverio S, Catena F, Ansaloni L, Gavioli M, Valentino M, Pinna AD. Water-soluble contrast medium (gastrografin) value in adhesive small intestine obstruction (ASIO): a prospective, randomized, controlled, clinical trial. *World J Surg*. 2008;32(10):2293–2304.
18. Zielinski MD, Haddad NN, Cullinane DC, et al. Multi-institutional, prospective, observational study comparing the Gastrografin challenge versus standard treatment in adhesive small bowel obstruction. *J Trauma Acute Care Surg*. 2017;83(1):47–54.
19. Chen SC, Lin FY, Lee PH, Yu SC, Wang SM, Chang KJ. Water-soluble contrast study predicts the need for early surgery in adhesive small bowel obstruction. *Br J Surg*. 1998;85(12):1692–1694.
20. Scotté M, Mauvais F, Bubenheim M, Cossé C, Suaud L, Savoye-Collet C, Plenier I, Pequignot A, Yzet T, Regimbeau JM. Use of water-soluble contrast medium (gastrografin) does not decrease the need for operative intervention nor the duration of hospital stay in uncomplicated acute adhesive small bowel obstruction? A multicenter, randomized, clinical trial (Adhesive Small Bowel Obstruction Study) and systematic review. *Surgery*. 2017;161(5):1315–1325.
21. Srinivasa S, Thakore N, Abbas S, Mahmood M, Kahokehr AA, Hill AG. Impact of gastrografin in clinical practice in the management of adhesive small bowel obstruction. *Can J Surg*. 2011;54(2):123–127.

