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Quality improvement project on the development of a management algorithm for iatrogenic perforations and the long-term impact on physician knowledge*

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ABSTRACT

Background and study aims Acute iatrogenic endoscopic perforations (AIEPs) can have high morbidity and mortality, especially colonic perforations. Knowledge of diagnosis and AIEP management can improve patient care. The aims of this study were to: develop an evidence-based AIEP management algorithm; study its short-term and long-term impact on physician knowledge; and evaluate physician knowledge using hypothetical clinical scenarios.

Methods An institutional AIEP management algorithm was created using the most current recommendations from the American Society for Gastrointestinal Endoscopy and the European Society of Gastrointestinal Endoscopy. Input from advanced endoscopists, nurses, and anesthesiologists was also obtained. We assessed change in physician knowledge using a 10-item questionnaire before (pretest), a standardized one-page AIEP educational material and algorithm immediately after (post-test) to test short-term retention, and 6 months later (6-month reassessment) to test long-term retention. With the 6-month reassessment, two clinical scenarios based on real AIEP were presented to evaluate application of knowledge.

Results Twenty-eight subjects (8 gastroenterology fellows and 20 practicing gastroenterologists) participated in the assessments. Pretest and immediate post-test accuracies were 75 % and 95 % ($P<0.01$), respectively. Six-month reassessment accuracies were 83.6 %, significantly worse compared to post-test accuracies ($P<0.05$), but significantly improved compared to pretest accuracies ($P<0.05$). Accuracies for clinical scenarios #1 and #2 were 67.5 % and 60.3 %, respectively. Fellows had similar accuracies when compared to practicing gastroenterologists.

Conclusions Using standardized methodology and a multidisciplinary approach, an AIEP management algorithm was created to improve patient care and alleviate physician and staff stress. In addition, we showed that a one-page educational document on perforations can significantly improve short-term and long-term physician knowledge, although periodic reeducation is needed.

* Meeting reports: These data were presented in part at the "Advancing Clinical Practice: GI Fellow-Directed Quality Improvement Projects" session of the DDW 2021, virtual online meeting.

Introduction

Iatrogenic intraperitoneal colonic perforations have been associated with significant morbidity and mortality with reported mortality rates of 5% to 25% [1]. Intraperitoneal perforations may lead to secondary peritonitis, which can lead to sepsis, multiorgan failure, and death [2]. Perforations that are recognized and treated immediately should have better outcomes than those acted on later [3]. In addition, perforations traditionally have been managed surgically, and a large part of the morbidity and mortality are related to anesthesia complications and postoperative events such as prolonged ileus, fascial dehiscence, and pulmonary embolism, leading to an average hospital stay of 1 to 3 weeks [2–4]. If identified immediately at the time of the index endoscopy, it is possible to close the perforations endoscopically with a 90% success rate, resulting in better outcomes [5].

Despite the significant success rate for closing intraperitoneal perforations endoscopically, there are issues with implementing a management protocol for acute iatrogenic endoscopic perforations (AIEPs). The rarity of AIEP, with reported rates of less than 1% of all endoscopies, makes it problematic for physicians who are not regularly exposed to or experienced in managing perforations [6,7]. In addition, intraprocedure management of perforations requires a coordinated effort among different team members including the endoscopist, nurse/technician, and anesthesiologist. Further complicating the matter is the high-stress situation of making decisions in a time-sensitive manner to prevent morbidity and mortality. All these issues center on the underlying problem of not having a universally accepted management protocol. The approach to AIEP could be comparable to dealing with a high-stress, high-morbidity situation such as cardiopulmonary resuscitation (CPR), and as such, a standard algorithm may help alleviate stress and improve outcomes.

Peery et. al revealed that approximately 17 million colonoscopies and upper endoscopies were performed in 2013 in the United States [8]. Despite the rarity of AIEP, it is likely that all gastroenterologists will experience such an event at some point during their careers. Improving patient outcomes related to AIEP was the basis of our quality improvement (QI) project.

The aims of this study were: to develop an evidence-based AIEP management algorithm that is available for quick reference in the gastroenterology lab; to study its short-term and long-term impact on physician knowledge; and to evaluate physician knowledge on management of perforations based on hypothetical clinical scenarios.

Methods

The study was conducted at Cedars-Sinai Medical Center (CSMC), an academic tertiary-care referral center, from January 2019 to October 2020. As this was a QI study that did not involve patients, Institutional Review Board approval was not required.

Endoscopy unit

The endoscopy unit is located within the main hospital building and consists of seven procedure rooms fully equipped for performing upper endoscopies and colonoscopies. Four of the rooms are also equipped with fluoroscopy for advanced endoscopic procedures. Both inpatient and outpatient procedures typically are performed in all the rooms; the average is 50 to 60 procedures per day. There are 47 gastroenterologists and 10 to 12 fellows each year who have privileges to perform procedures. Five full-time advanced endoscopists are available to help other gastroenterologists, if needed. Each procedure room is staffed with an anesthesiologist, a certified gastroenterology registered nurse, and a surgical technician. Some rooms may be staffed by an attending supervising a general or advanced gastroenterology fellow. In the event a perforation occurs, the intraoperative nurse or technician notifies the charge nurse via telephone to obtain antibiotics and other equipment as necessary. If hemodynamic instability or a cardiorespiratory arrest occurs, the anesthesiologist is responsible for conducting advanced cardiac life support (ACLS). A Code Blue team with training in ACLS is always on standby at the hospital for more assistance. All procedure rooms are equipped with through-the-scope clips (TTSCs), over-the-scope clips (OTSCs), and nasogastric (NG) tubes. Other advanced endoscopic closure techniques such as stents and suturing devices are in the advanced endoscopy rooms.

Development of an evidence-based AIEP management algorithm

To develop an evidence-based AIEP management algorithm, the most current recommendations from the American Society for Gastrointestinal Endoscopy, the European Society of Gastrointestinal Endoscopy, and the American Gastroenterological Association (AGA) on endoscopic perforations were reviewed and combined into a concise management algorithm for easy use [9–12]. In addition, a PubMed literature review on endoscopic perforation was performed using the keywords “endoscopy perforation” and “management of endoscopic perforations.” Abstracts were then reviewed. Only full-length articles on endoscopic perforations relating to identification, diagnosis, and management of perforations were reviewed [1,5,7,13–16]. A preliminary AIEP management algorithm was then created. We presented our algorithm at monthly multidisciplinary conference known as the MD-RN Committee. We sought input from advanced endoscopists, nurses, technicians, and anesthesiologists at this committee. The MD-RN meetings are held every month to discuss ways to improve gastroenterology lab efficacy and function, and patient safety, and can be attended by any of the gastroenterology lab team. During the process of creating the final algorithm, any disagreements were resolved based on a majority vote. For instance, a preliminary version of the algorithm assigned tasks to specific members, but based on majority vote, this was not incorporated into the final algorithm because it was deemed too inflexible and could thus lead to inefficiencies in the AIEP algorithm. A formal validated

process for achieving consensus such as the Delphi method was not performed.

The interdisciplinary discussion also highlighted some of the issues that could affect the AIEP algorithm. For example, the required antibiotics were not stocked in the procedure area and might result in delay in appropriate, timely treatment. Based on CSMC antibiogram, the recommended antibiotics were ceftriaxone and metronidazole. The antibiogram was created by the Department of Epidemiology at CSMC based on cultures taken from patients throughout the hospital, including the gastroenterology lab, and is updated annually. To have these medications available for immediate use after an AIEP, we have since changed the formulary in our gastroenterology lab to routinely stock these medications. There are three medication dispensing systems throughout the gastroenterology lab and they are stocked with the recommended antibiotics.

Creation of an emergency AIEP kit

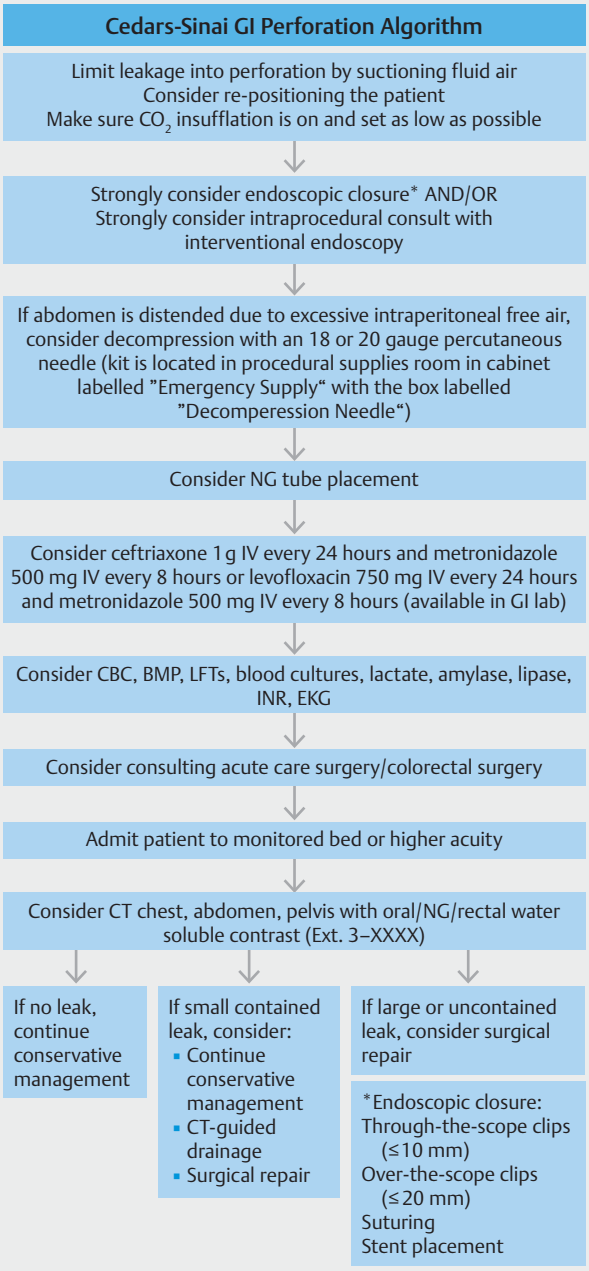
During the creation of the final algorithm, it was discovered that decompression needles were not available in our gastroenterology lab. During an AIEP, tension pneumoperitoneum can occur quickly, leading to rapid decline in clinical status and hemodynamic instability, necessitating quick management to prevent morbidity and mortality. The two leading locations for storing the kits, based on the MD-RN Committee discussion, were either in each of the procedure rooms or in the supply room. Based on the rarity of AIEP, the consensus of the committee was storage in the supply room. Thus, we have now stocked both 18-gauge and 20-gauge decompression needles located in a box clearly labeled "Decompression Needle" in a cabinet labeled "Emergency Supply" in the supply room, which is in the procedure area of the gastroenterology lab (**Supplementary Fig. 1** and **Supplementary Fig. 2**).

Dissemination of the AIEP management algorithm

▶ **Fig. 1** shows the final AIEP management algorithm. To circulate the finalized algorithm, a 1-hour lecture was held for the nurses and technicians, and emails were sent to the gastroenterologists and anesthesiologists. In addition, the finalized algorithm was posted in the gastroenterology lab at the charge nurse station with high foot traffic. Finally, the algorithm was placed in a procedure resource binder in each of the seven procedure rooms (**Supplementary Fig. 3**, **Supplementary Fig. 4**), which contains important information for the intraoperative nurse to reference if needed. In the binder, there is now a tab labeled "CSMC Perforation Guideline" for easy access.

Evaluation of physician knowledge

To evaluate the impact of this QI project, it would be ideal to study a real AIEP situation to evaluate direct clinical improvement in outcomes. Due to the rarity and unexpected nature of perforations, this was not possible. Therefore, physician knowledge, a surrogate marker of clinical outcome, was assessed first by using a pretest, post-test, and 6-month reassessment. Subsequently, we created two clinical scenarios to apply knowledge of AIEP management and simulate physician response to perforations. Participants included practicing gastroenterologists (private practice and academic) and fellows who possessed active privileges at the gastroenterology lab.



▶ **Fig. 1** Management algorithm for acute iatrogenic endoscopic intraperitoneal perforations.

Questionnaire: Short- and long-term knowledge retention

A pretest was first given to physicians (▶ **Fig. 2**) to assess knowledge about identifying and treating AIEP. The questionnaire was developed to assess fundamental knowledge about perforations regarding their common locations, etiologies, recognition, management, and associated complications. The questionnaire was completed before (pretest) and immediately after (post-test) participants read a standardized one-page

Perforation Guidelines General Assessment

___ Fellow ___ Attending
___ Pre-assessment ___ Post-assessment ___ 6-month reassessment

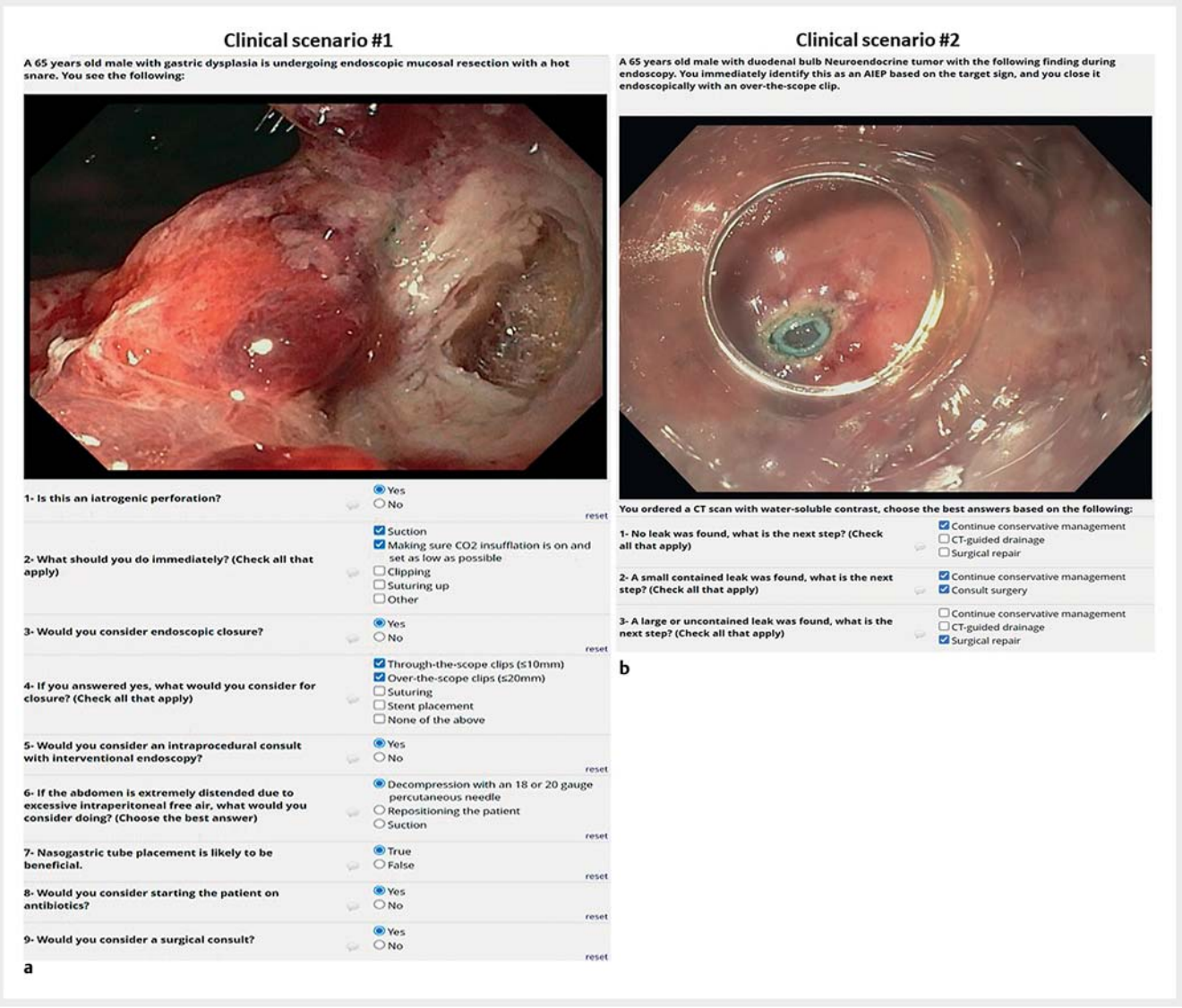
1. When a perforation occurs and the patient has significant abdominal distension with respiratory distress, what should be the next step to consider?
   a. NG tube placement
   b. Surgery
   c. Percutaneous decompression needle
   d. Intubation
2. Is CO2 or air insufflation preferable when a perforation occurs?
   a. CO2 insufflation
   b. Air insufflation
3. What imaging modality is the most sensitive in detecting a perforation?
   a. X ray
   b. CT with IV contrast
   c. CT with water soluble contrast
   d. MRI
4. In a routine colonoscopy, which part of the colon is the most common site of perforation?
   a. Rectum
   b. Sigmoid colon
   c. Descending colon
   d. Transverse colon
   e. Ascending colon
   f. TI
5. Which of the following is the cause for most perforations in a routine colonoscopy?
   a. Mechanical trauma
   b. Endoscopic resection/dissection
   c. Thermal injury
   d. Dilation
6. In an average risk individual at Cedars-Sinai, what antibiotics are recommended when a perforation occurs?
   a. Ceftriaxone
   b. Metronidazole
   c. Levofloxacin
   d. Ceftriaxone and metronidazole
   e. Meropenem
7. According to ESGE for the management of iatrogenic gastric and esophageal perforations, up to what size are TTS clips appropriate?
   a. 5mm
   b. 10mm
   c. 15mm
   d. 20mm
8. According to ASGE, in an upper endoscopy, which of the following procedures are NOT considered to carry a significant increased risk of perforation?
   a. Endoscopic dilation
   b. Mucosal resection/submucosal dissection
   c. Variceal band ligation
   d. Foreign body removal
9. You are performing a routine colonoscopy, when inadvertently, a perforation occurs in the sigmoid colon. You successfully suction the area and place a clip to close the perforation. You start antibiotics and admit the patient for monitoring. The patient has stable vital signs and minimal distension. The next day, a CT scan shows extra luminal air without contrast extravasation. What should be done next?
   a. Consult surgery
   b. Repeat colonoscopy
   c. Continue current management
   d. Repeat CT scan in 2 days
10. Which of the following therapeutic maneuvers are associated with the highest risk of iatrogenic perforation?
    a. Stricture dilation from caustic injury
    b. Foreign body removal
    c. Endoscopic mucosal dissection
    d. Variceal sclerotherapy

▶ **Fig. 2** Ten-question pretest, post-test, and 6-month post-test assessment for iatrogenic endoscopic perforations, a quality improvement study in the gastroenterology lab.

educational material based on the algorithm (**Supplementary Fig. 5**). This educational material covered information related to the algorithm and also included most common locations and reasons for perforations for both upper endoscopy and colonoscopy. The same assessment tool was given 6 months later (6-month reassessment) to evaluate for long-term knowledge retention.

Clinical scenarios: Application of physician knowledge

The two clinical scenarios then followed the 6-month reassessment, which were based on actual AIEP experienced at CSMC (▶ **Fig. 3**). For each clinical scenario, brief background information and one photograph were provided, and subsequently physicians answered questions designed to assess their response in identification and management of perforations.



▶ **Fig. 3** **a** Clinical scenario #1 showing perforation after endoscopic mucosal resection at the gastric cardia. **b** Clinical scenario #2 showing perforation (target sign) after endoscopic mucosal resection in the duodenal bulb.

Statistical analysis

Data were presented as frequency (percentage) for categorical and median (interquartile range) for continuous variables. Two-tailed *t*-test were used. Microsoft Excel (Microsoft Corporation, Redmond, Washington, United States) was used for data analysis.

Results

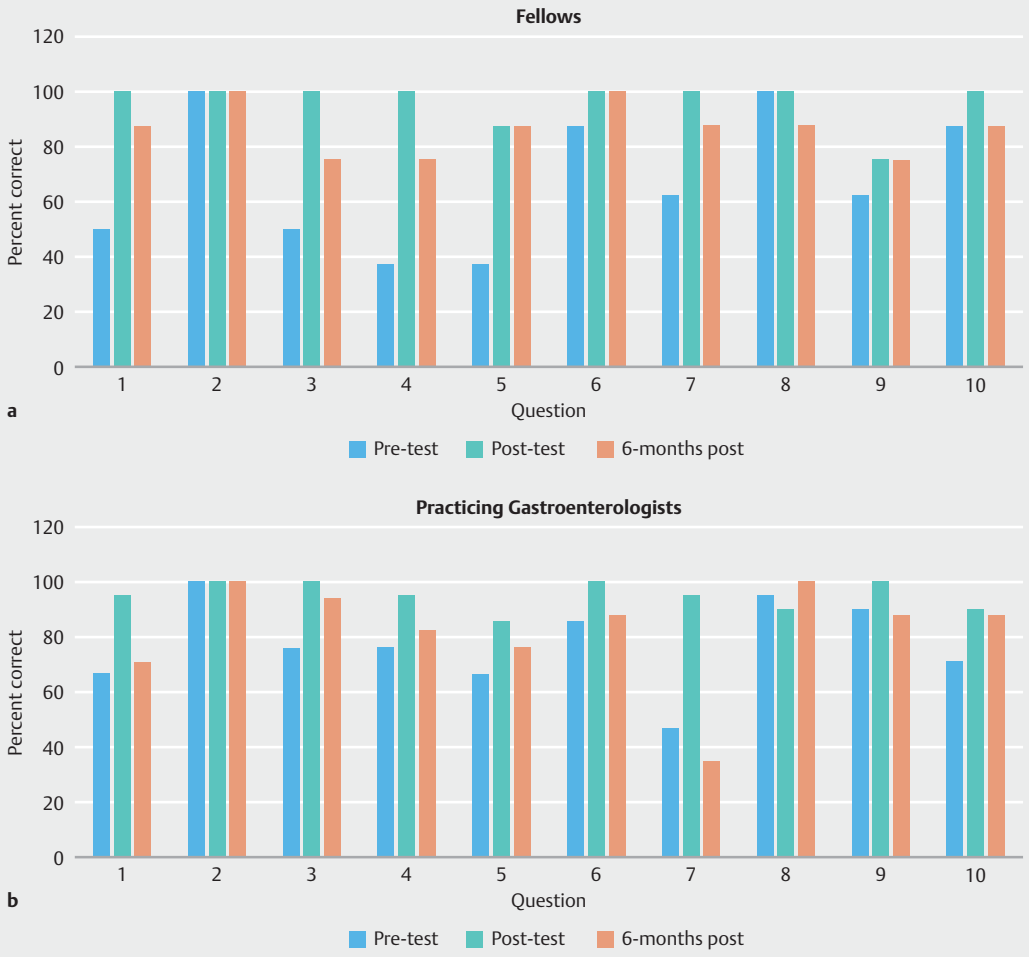
Demographics

Twenty-eight physicians (8 fellows and 20 practicing gastroenterologists) participated in the assessments. Median age was 39.5 years with a median of 11 years of experience. Ten physicians had experienced an AIEP before (▶ **Table 1**).

▶ **Table 1** Demographics of physicians participating in assessments.

Physician type, n (%)	
▪ Practicing gastroenterologists	20 (72)
▪ Fellows	8 (28)
Gender, n (%)	
▪ Male	20
▪ Female	8 (28)
Age, median years (IQR)	39.5 (36.25–44.75)
Experience, median years (IQR)	11 (7.25–17)
Previous AIEP experience, n (%)	10 (36)

IQR, interquartile range; AIEP, acute iatrogenic endoscopic intraperitoneal perforation.



▶ **Fig. 4** **a** and **b** Pretest, post-test, and 6-month post-assessment accuracies per question for fellows and practicing gastroenterologists, respectively.

Evaluation of physician knowledge

Questionnaire: Short- and long-term knowledge retention

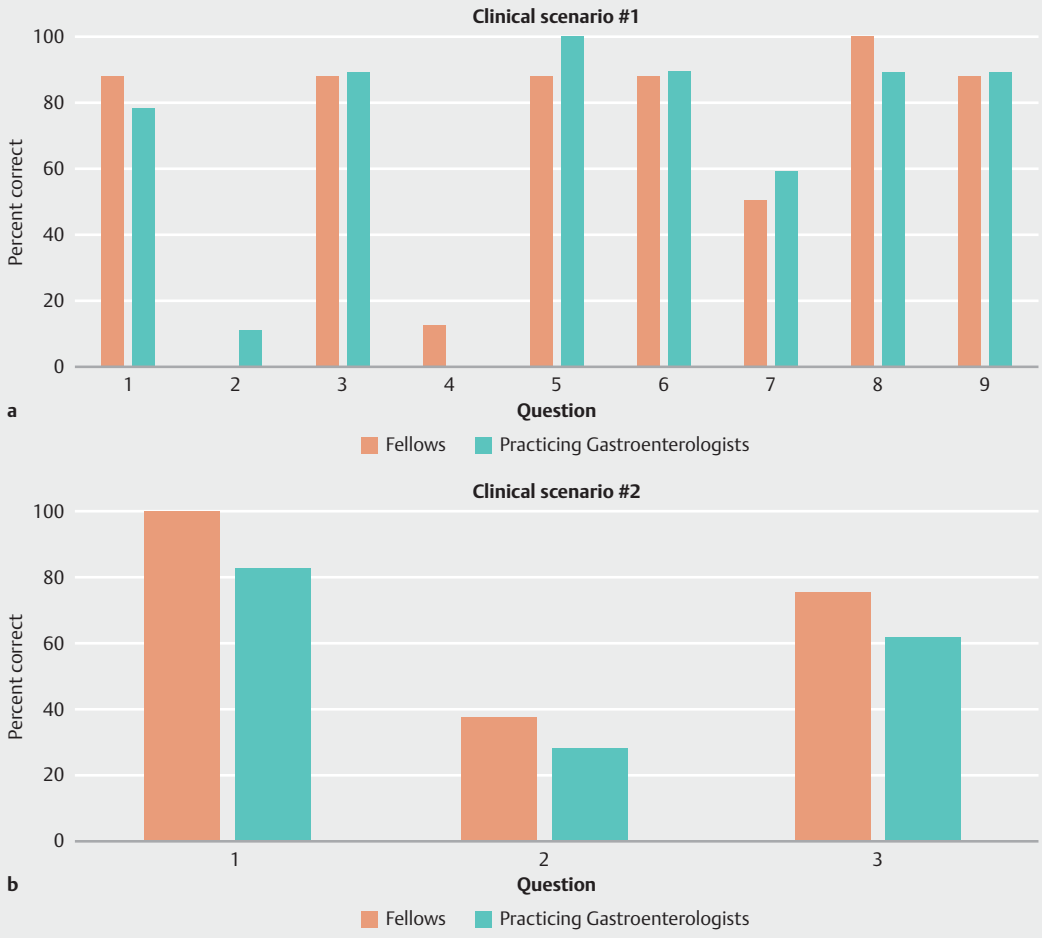
On pretest, the biggest gaps in knowledge were questions 4 (most common site of perforation during routine colonoscopy) and 5 (most common cause of perforation during routine colonoscopy, with 37.5 % accuracy each among the fellows. Similarly, low scores were seen for question 7 (TTSC for max 10-mm perforation closures) with 47.6 % accuracy for the practicing gastroenterologists (▶ **Fig. 4**).

Overall pretest and immediate post-test accuracies were 75 % and 95 % ($P<0.01$), respectively (▶ **Fig. 4**). The fellows' pretest and post-test accuracies were 67.5 % and 96 % ($P<0.01$), and the practicing gastroenterologists' pretest and post-test accuracies were 78 % and 95 % ($P<0.01$), respectively. Neither pretest nor post-test accuracies were significantly different when comparing fellows to practicing gastroenterologists.

On 6-month reassessment, the overall accuracies for all respondents were 83.6 % (▶ **Fig. 4**), which was significantly improved compared to pretest accuracies of 75 % ($P=0.01$) but worse compared to immediate post-test accuracies of 95 % ($P<0.0001$). Fellows had 86.3 % accuracy and the practicing gastroenterologists had 82.4 % accuracy. Fellows showed long-term improvement in questions 4 and 5, while question 7 was still the most often incorrectly answered (35.3 %) for the practicing gastroenterologists (▶ **Fig. 4**).

Clinical scenarios: Application of physician knowledge

Overall accuracies for clinical scenarios #1 and #2 were 67.5 % and 60.3 %, respectively. Fellows' accuracy for clinical scenario #1 (▶ **Fig. 3a**) was 66.7 % compared to 67.1 % for practicing gastroenterologists. None of the fellows were able to answer question 2 correctly (What should you do immediately following identification of an AIEP?), while none of the practicing gastroenterologists felt they needed to consult interventional endoscopy (IE) (question 4). Fellows' accuracy for clinical scenario #2 (▶ **Fig. 3b**) was 70.8 % compared to 56.6 % for practicing gastroenterologists ($P=0.09$). Question 2 was most often incorrectly answered (What is the next step after a small contained leak is found on imaging after endoscopic closure of a perforation?) for both fellows (37.5 %) and practicing gastroenterologists (27.8 %) (▶ **Fig. 5**).



▶ **Fig. 5** **a** Accuracies for clinical scenario #1 and **b** clinical scenario #2 comparing fellows (red) and practicing gastroenterologists (green).

Discussion

Using standardized methodology and a multidisciplinary approach, a management algorithm was created with the goal of improving patient outcomes in the event of an AIEP during endoscopy. Physicians showed significant improvement in short- and long-term retention about AIEP management after reading a one-page evidence-based education document. This study shows potential benefits in patient care and physician knowledge from a simple QI project. This methodology can be easily adapted to other QI studies in medicine and help with assessment of the impact of such a project on its intended audience. Of note, an informal process for achieving consensus was conducted, and a formal process for achieving consensus, such as using the Delphi method was not performed.

Managing acute endoscopic intraperitoneal perforations is extremely time-sensitive and requires a multidisciplinary approach involving mainly gastroenterologists, anesthesiologists, nurses, technicians, surgeons, and interventional radiologists. Diagnostic upper endoscopies and colonoscopies have a reported perforation rate of 0.0009 % to 0.05 % [7] and 0.03 % to 0.8 % [6], respectively. Higher-risk procedures, which include dilation of complex esophageal strictures, have reported perforation rates of 10 % to 17 % [6, 9]. Given the growing number of endoscopy procedures performed in the United States (~17.7 million procedures in 2013 [8]), the absolute number of perforations may be higher than what is reported in the current literature. Indeed, from our study, 36 % of the physicians experienced an AIEP before. Thus, the basis of our QI study was to improve patient outcomes related to AIEPs. Of note, we focused on intraperitoneal gastrointestinal perforations, mainly gastric and colonic perforations, as these are likely the most common perforations encountered by most practicing gastroenterologists. As such, we did not include retroperitoneal perforations or duodenal perforations that can occur during endoscopic retrograde cholangiopancreatographies or duodenal adenoma resections.

QI in healthcare aims to develop methods that improve patient care and outcomes [15]. In this study, the initial step was creating an AIEP management algorithm based on the most up-to-date recommendations, literature review, and expert feedback. There is abundant evidence regarding the adequacy of endoscopic management of intraperitoneal perforations. The AGA recently published an expert review on endoscopic man-

agement of gastrointestinal perforations. Their recommendations are largely similar to what is presented in our algorithm, but the review has a more detailed description of perforations for specific gastrointestinal sites such as gastric, duodenal, and colon [11]. However, the actual process of managing a patient with AIEP is lacking. This is especially true during the immediate period following identification of an AIEP. This period is very stressful, given that the endoscopist may be surprised or shaken that a perforation has occurred and it is also most important, given that multiple interventions in a stepwise process need to be carried out by multiple providers in a time-sensitive manner. Therefore, we sought to create an AIEP management algorithm to "streamline" the management process and serve as a guide, like the management algorithm for CPR. Our algorithm has been introduced to the physicians in our study and was also posted in each of our endoscopy rooms to serve as a reference. Kowalczyk et. al in 2011 published a similar QI project [15]. One key difference between our algorithm and those developed by Kowalczyk et. al is our inclusion of the initial step of limiting any complications when a perforation occurs. This includes making sure CO_2 insufflation is on and set as low as possible to limit extraluminal gas development; suctioning the area to limit extraluminal leakage; and considering repositioning the patient so the perforation is in a non-dependent position such that the intraluminal fluid does not leak out into the peritoneum through the perforation site. These initial steps may be the most important activities to limit serious complications including tension pneumoperitoneum/mediastinum, infection/abscess, and overall hemodynamic instability [11]. An additional key difference is that Kowalczyk et. al had three separate algorithms based on the location of perforation in the gastrointestinal tract; instead, we have one algorithm regardless of location given the largely similar management options. The only really different management option would be to strongly consider placing a NG tube for upper gastrointestinal tract perforations to limit leakage extraluminally and keep the perforation as dry as possible to promote healing, although it is not critically important for lower gastrointestinal procedures. Another key difference is that we included a step to consult an IE to assist in endoscopic perforation closure. Given an IE's expertise and their availability at our gastroenterology lab, we felt that this was an important step to include in our algorithm. Finally, we included information on the different endoscopic closure methods and further detailed the different use of TTSCs and OTSCs based on perforation size. Both the recent AGA and ESGE reviews have highlighted the gradual shift to more advanced techniques of closing perforations including OTSC and suturing [11, 12]. With increasing endoscopic advancements, there has been a significantly increased shift toward endoscopic closure of perforations with one large study revealing an increase from 6.7 % to 72.7 % [17]. Advanced clipping techniques, specifically OTSC, have largely contributed to successful endoscopic closure of perforations [18]. These clips are more secure than TTSCs and can close perforations up to 20 mm while TTSCs are limited to 10 mm. This is especially useful for perforations occurring during diagnostic colonoscopies, which have been shown to have larger defects than therapeutic colonoscopies [19]. While OTSC may be preferred for left-sided colonic perforations, it is not recommended for right-sided colonic perforations because of the difficulty in reaching the right colon with the OTSC device [11].

From our 10-item questionnaire, our results showed that reading a one-page educational document based on the AIEP algorithm led to a significant improvement in both immediate (75 % vs. 95 %) and long-term knowledge (75 % vs. 83.6 %) about the diagnosis and appropriate management of AIEP among physicians. Our results also suggest the need for periodic reeducation, given the significant decrease in accuracy when comparing immediate short-term knowledge to 6-month long-term knowledge (95 % vs. 83.6 %). The reason for this decrease in accuracy could have been the physicians remembering the questions during the immediate post-assessment, leading to artificially higher accuracy. Another potential reason includes the rarity of AIEP and thus not being familiar with the AIEP management algorithm on a regular basis and forgetting information over time. Like the need for periodic recertification with CPR, we suggest that periodic reeducation is needed for AIEP.

When evaluating the accuracy of each question, questions 4 and 5 (▶ **Fig. 4**) were the ones most often answered incorrectly by fellows and question 7 was the one most often answered incorrectly by practicing gastroenterologists. Questions 4 and 5 pertained to knowledge on the most common location and reason for perforation during a routine colonoscopy. The fellows showed improvement in accuracy rates for these questions, but given the initial high rates of inaccuracy, it seems prudent to educate fellows, especially those who are beginning their gastroenterology training, so that they can understand likely causes and locations for perforation and take necessary precautions. In addition, it is important that fellows retain this knowledge throughout their training and career, and this was demonstrated on 6-month reassessment. The practicing gastroenterologists were unable to show long-term knowledge retention for question 7, which tested their knowledge on the appropriate use of TTSCs based on perforation size. Endoscopic management mainly involves the use of clips (TTSC or OTSC), but also can include stents and sutures [20]. Given that a systematic review and meta-analysis found that successful endoscopic closure of AIEP was achieved in 419 of 466 cases (90 %) [5], we highly recommend considering endoscopic closure of a perforation. Our algorithm features the different methods for endoscopic closure of perforations, so that information is readily available as a reference when needed.

When evaluating the application of physician knowledge to two clinical scenarios designed to simulate perforations, the accuracies were surprisingly low with 67.5 % and 60.3 %, respectively. A difference in accuracy rates between the assessments and the two clinical scenarios may reflect difficulties in applying theoretical knowledge to clinical practice. However, it was concerning to find that none of the fellows answered clinical scenario #1, question 2 correctly, which tested knowledge on the immediate steps to take following identification of an AIEP. These measures may arguably be the most important in limiting morbidity and mortality, given that they are the first steps in our algorithm. A potential reason for no one answering this

question correctly could be related to the question having multiple answers ("Check all that apply"), and we considered answers incorrect if not all the correct answers were chosen. Further, the images do not give all the information needed to make appropriate clinical decisions. For example, accurate assessment of the size of perforation is not possible. In retrospect, we should have presented videos instead of pictures for these clinical questions.

Despite the discrepancy in overall accuracy between the assessments and clinical scenarios, certain topics including adjunctive therapies that were tested on the assessments did translate well on the clinical scenarios. For instance, knowledge about tension pneumoperitoneum as a complication of AIEP and need for decompression with a percutaneous needle was tested on both the assessments (question 1) and clinical scenario #1, question 6 [21]. Accuracy rates forf both fellows and practicing gastroenterologists improved in the assessments, and this improvement was also apparent in clinical scenario #1 with 87.5 % and 88.8 % accuracy rates among the fellows and the practicing gastroenterologists, respectively. Certain adjunctive therapies need to be reemphasized, given low accuracy rates. For instance, clinical scenario #1, question 7 showed relative lack of knowledge regarding the benefits of using NG tubes in gastric perforations with accuracies of 50 % and 58.8 % among the fellows and the practicing gastroenterologists, respectively. NG tubes are beneficial in perforations during upper endoscopy as they help to limit gastric contents from leaking extraluminally and also keeping the perforated area dry to promote healing [10].

There were some interesting findings from the clinical scenarios. For clinical scenario #1, none of the practicing gastroenterologists in the current study decided to consult an IE. IEs have more experience with advanced procedures and difficult situations. We strongly recommend consulting an IE because they are experienced colleagues who can alleviate stress, help to avoid worsening the situation, and improve overall patient outcome. If an IE is not available, then each practicing gastroenterologist should be familiar with his/her comfort level for managing perforations and should have a low threshold for consulting a surgeon. Another interesting finding was for clinical scenario #2 for which only 62.5 % and 50 % of the fellows and practicing gastroenterologists, respectively, would have consulted a surgeon when a small, contained leak was found. We strongly recommend surgical consultation in the setting of any identified leak as it may help to avoid further complications, if such a consultation has not already been made.

Limitations of our study include the small sample size of the participants and the relatively short period used to assess knowledge retention. Because AIEP are rare and life-threatening, we were not able to assess implementation of knowledge in real clinical settings. Future studies could include randomizing gastroenterologists who experience a perforation to follow the algorithm vs. managing the perforations on their own and evaluating the clinical outcomes between the two arms. Although future prospective, randomized, multicenter studies may be hard to accomplish due to ethical and safety concerns, they are needed to validate our algorithm and its impact on patient outcomes. However, physician knowledge is often thought of as a marker of good patient outcomes. The assumption is implicit and often at every level of education to becoming a physician, there are tests of knowledge. This test assumes that improvement in physician knowledge is likely to improve patient outcome. Another potential limitation is the reproducibility of our study at other centers. This is an inherent problem with QI projects, in large part due to their complexity. We wanted to create a study that was relatively easy to implement, analyze, and reproduce. In an effort to standardize our study, we used the Plan-Do-Study-Act (PDSA) method for this study, which is commonly used in QI projects [22]. We completed multiple cycles of the PDSA method with the input of other physicians and nurses to finish this QI project. We also adhered to the Standards for QUality Improvement Reporting Excellence (SQUIRE) 2.0 guidelines in reporting our study [23]. Another limitation is that we did not include an example of a colonic perforation as part of our clinical scenarios. We acknowledge that in a real-world situation, management of a gastric perforation is different from a colonic perforation. However, the objective of the clinical scenarios and the overall study was to educate physicians on the general principles for managing gastrointestinal intraperitoneal perforations. These general principles include limiting leakage through the perforation site, antibiotics, use of TTSC and OTSC, and computed tomography with water soluble contrast to evaluate for successful closure. These general principles are included in our algorithm and can be applied to perforation whether it be in the upper or lower gastrointestinal tract. This highlights the flexibility of our algorithm in being able to apply the algorithm to different perforation sites within the gastrointestinal tract.

Conclusions

In conclusion, an AIEP management algorithm was created to coordinate actions of different providers for patient management in a timely manner. This management algorithm is now posted in each of our gastrointestinal endoscopy rooms to serve as a reference when needed, which can save time and improve overall patient outcomes. Indirect methods of evaluating patient outcomes through assessing physician knowledge revealed improved physician knowledge in the short and long term, although periodic reeducation is recommended. Finally, simulated clinical scenarios of perforations showed that physicians may need further emphasis on certain topics. Our simple project can be used as a framework for future QI projects in other areas of medicine. Future research is needed to evaluate whether implementation of an AIEP management algorithm improves patient outcomes.

Competing interests

The authors declare that they have no conflict of interest.

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