A Quality Improvement Project on the Development of a Management Algorithm for Iatrogenic Perforations and the Long-Term Impact on Physician Knowledge


Affiliations below.

DOI: 10.1055/a-1914-6358


Conflict of Interest: The authors declare that they have no conflict of interest.

Abstract:
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Institutional AIEP management algorithm was created using the most current recommendations by ASGE/ESGE. Input from advanced endoscopists, nurses, and anesthesiologists was also obtained.

We assessed change in physician knowledge using a 10-item questionnaire before (pre-test) - 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, 2 clinical scenarios based on real AIEP were presented to evaluate application of knowledge.

Results
28 subjects (8 gastroenterology fellows and 20 practicing gastroenterologists) participated in the assessments. Pre-test and immediate post-test accuracies were 75% and 95% (p<0.01), respectively. 6-month reassessment accuracies were 83.6%, significantly worse compared to post-test accuracies (p<0.05), but significantly improved compared to pre-test 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. Additionally, we showed that a brief one-page educational material on perforations can significantly improve short-term and long-term physician knowledge, though periodic re-education is needed.
Title: A Quality Improvement Project on the Development of a Management Algorithm for Iatrogenic Perforations and the Long-Term Impact on Physician Knowledge

Short title: Acute iatrogenic perforation in the GI lab

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Conflicts of interest: None

Acknowledgements: None

This data was presented in part at the “Advancing Clinical Practice: GI Fellow-Directed Quality Improvement Projects” session of the DDW 2021, virtual online meeting.

Abbreviations:
AIEP: Acute iatrogenic endoscopic perforations
CPR: Cardiopulmonary resuscitation
CSMC: Cedars-Sinai Medical Center
GI: Gastrointestinal
IE: Interventional endoscopy
NG: Nasogastric
OTSC: Over-the-scope clips
QI: Quality improvement
TTSC: Through-the-scope clips
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Keywords:
Algorithms; Endoscopy; Gastrointestinal/adverse effects; Intestinal perforation/therapy; Quality improvement; Surveys and Questionnaires
Introduction

Iatrogenic intraperitoneal colonic perforations have been associated with significant morbidity and mortality with reported mortality rates of 5-25% [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]. Additionally, perforations have been traditionally 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 1-3 weeks [2, 3, 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 of closing intraperitoneal perforations endoscopically, there are issues with implementing a management protocol for acute iatrogenic endoscopic perforations (AIEP). The rarity of AIEP, with reported rates of less than 1% of all endoscopies, makes it problematic for the physicians who are not regularly exposed to or experienced in managing perforations [6, 7]. Additionally, intraprocedural 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 be helpful to alleviate stress and improve outcomes.

Peery et al revealed that ~17 million colonoscopies and upper endoscopies were performed in 2013 in the U.S. [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 GI 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.

**Materials and 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 7 procedure rooms fully equipped for performing upper endoscopies and colonoscopies. Out of these, four of the rooms are also equipped with fluoroscopy for advanced endoscopic procedures. All rooms generally have both inpatient and outpatient procedures performed with an average of 50-60
procedures per day. There are 47 gastroenterologists and 10-12 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 intra-operative 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 (TTSC), over-the-scope clips (OTSC), 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**

In order to develop an evidence-based AIEP management algorithm, the most current recommendations by ASGE/ESGE/AGA on endoscopic perforations were reviewed and combined into a concise management algorithm for easy use [9, 10, 11, 12]. Additionally, 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, 14, 15, 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 the GI lab efficacy and functioning, and patient safety and can be attended by any of the GI 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 of 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 GI lab and is updated annually. To have these medications available for immediate use after an AIEP, we have since changed the formulary in our GI lab to routinely stock these medications. There are 3 medication dispensing systems throughout the GI 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 GI 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 to store 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 to store it in the supply room. Thus, we have now stocked both an 18-gauge and 20-gauge decompression needle located in a box clearly labelled “Decompression Needle” in a cabinet labeled “Emergency Supply” in the supply room which is in the procedure area of the GI lab. (Supplementary Figures 1-2).

**Dissemination of the AIEP management algorithm**

Figure 1 shows the final AIEP management algorithm. To circulate the finalized algorithm, a 1-hr lecture was held for the nurses and technicians, and e-mails were sent to the gastroenterologists and anesthesiologists. Additionally, the finalized algorithm was posted in the GI lab at the charge nurse station with high-foot traffic. Finally, the algorithm was placed in a procedural resource binder in each of the 7 procedure rooms (Supplementary Figures 3-4) which contains important information for the intra-operative nurse to reference if needed. In the binder, there is now a tab labelled “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 pre-test, post-test, and 6-month reassessment. Subsequently, we created 2 clinical scenarios to apply knowledge of AIEP management and simulate physicians’ response to perforations. Participants included practicing
gastroenterologists (private practice and academic) and fellows who possessed active privileges at the GI lab.

Questionnaire: Short-term and long-term knowledge retention

A pre-test was first given to physicians (Figure 2) to assess knowledge in identification and treatment of AIEP. The questionnaire was developed to assess the fundamental knowledge of perforations regarding their common locations, etiologies, recognition, and management and associated complications. The questionnaire was completed before (pre-test) and immediately after (post-test) participants read a standardized one-page educational material based on the algorithm (Supplementary Figure 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 2 clinical scenarios then followed the 6-month reassessment, which were based on actual AIEP experienced at CSMC (Figure 3). For each clinical scenario, a brief background information and one photograph were provided, and subsequently physicians answered questions designed to assess their response in identification and management of perforations.

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

Results

Demographics

28 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 experienced an AIEP before (Table).

Evaluation of physician knowledge

Questionnaire: Short-term and long-term knowledge retention

On pre-test, 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 (Figure 4).

Overall pre-test and immediate post-test accuracies were 75% and 95% (p<0.01), respectively (Figure 4). The fellows’ pre-test and post-test accuracies were 67.5% and 96% (p<0.01), and the practicing gastroenterologists’ pre-test and post-test accuracies were 78% and 95% (p<0.01), respectively. Neither pre-test 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% (Figure 4), which was significantly improved compared to pre-test 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 incorrectly answered (35.3%) for the practicing gastroenterologists (Figure 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 (Figure 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 (Figure 3B) was 70.8% compared to 56.6% for practicing gastroenterologists (p=0.09). Question 2 was the most 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%) (Figure 5).

Discussion

Using standardized methodology and a multidisciplinary approach, a management algorithm was created with a goal to improve patient outcomes in the event of an AIEP during endoscopy. Physicians showed significant improvement in short-term and long-term retention on AIEP
management after reading a short one-page evidence-based educational material. 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 0.0009-0.05% [7] and 0.03-0.8% [6], respectively. Higher risk procedures, which include dilation of complex esophageal strictures have reported perforation rates of 10-17% [6, 9]. Given the growing number of endoscopy procedures performed in the U.S. (~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 AIEP. Of note, we focused on intraperitoneal GI 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 ERCPs 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 the endoscopic management of GI 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 GI 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 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 CO2 insufflation is on and set as low as possible to limit extraluminal gas development; suction the area to limit extraluminal leakage; and consider repositioning the patient so 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 3 separate algorithms based on the location of perforation in the GI tract; instead, we have one algorithm regardless of location given the largely similar management options. The only real different management option would be to strongly consider placing a NG tube for upper GI tract perforations to limit leakage extraluminally and keep the perforation as dry as possible to promote healing, while it is not critically important for lower GI procedures. Another key difference is that we included a step to consult IE to assist in endoscopic perforation closure. Given IE’s expertise and their availability at our GI 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 TTSC and OTSC 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 towards endoscopic closure of perforations with one large study revealing an increase from 6.7% to 72.7% [17]. Advanced clipping techniques, specifically OTSC, has largely contributed to successful endoscopic closure of perforations [18]. These clips are more secure than TTSC and can close perforations up to 20mm while TTSC are limited to 10mm. 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 material 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 re-education, 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 accuracies. Another potential reason includes the rarity of AIEP and thus not being familiar with AIEP management algorithm on a regular basis and forgetting information over time. Like the need for periodic re-certification with CPR, we suggest periodic re-education is needed for AIEP.

When evaluating the accuracy of each question, questions 4 and 5 (Figure 4) were answered the most incorrectly among fellows and question 7 was answered most incorrectly among practicing gastroenterologists. Questions 4 and 5 pertained to knowledge on 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 GI training so that they can understand likely causes and locations for perforation and take necessary precautions. Additionally, 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 TTSC based on perforation size. Endoscopic management mainly
involves the use of clips (TTSC or OTSC), but also can include stents and sutures [20]. Given a systematic review and meta-analysis found that successful endoscopic closure of AIEP was achieved in 419/466 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 it is readily available as a reference when needed.

When evaluating the application of physician knowledge to 2 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 2 clinical scenarios may reflect difficulties in applying theoretical knowledge onto 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 they are the first steps of 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 choices were chosen. Further, the images do not give all the information needed to take appropriate clinical decisions. For example, the 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 on tension pneumoperitoneum as a
complication of AIEP and need for decompression with percutaneous needle was tested on both
the assessments (question 1) and clinical scenario #1, question 6 [21]. Accuracy rates of 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 re-emphasized 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 IE. Interventional
endoscopists have more experience with advanced procedures and difficult situations. We
strongly recommend consulting IE since having an experienced colleague can alleviate stress,
help to avoid worsening the situation, and improve overall patient outcome. If IE is not available,
then each practicing gastroenterologist should be familiar with his/her comfort level of managing
perforations and should have a low threshold for consulting surgery. Another interesting finding
was found in clinical scenario #2 where there were only 62.5% and 50% of the fellows and
practicing gastroenterologists, respectively, consulting surgery 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 not already consulted prior.
Limitations of our study include the small sample size of the participants, and the relatively short period used to assess knowledge retention. Since AIEP are rare and life-threatening, we were not able to assess the 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 patients’ 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 outcomes. 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 its 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 GI intraperitoneal perforations.
These general principles include limiting leakage through the perforation site, antibiotics, use of TTSC and OTSC, and CT 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 GI or lower GI tract. This highlights the flexibility of our algorithm in being able to apply the algorithm to different perforation sites within the GI tract.

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 GI 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-term and long-term, though periodic re-education is recommended. Finally, simulated clinical scenarios of perforations showed 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 if the implementation of an AIEP management algorithm improves patient outcomes.

References:


**Figure Legends**

**Figure 1.** Management Algorithm for Acute Iatrogenic Endoscopic Intraperitoneal Perforations (adapted from Kowalczyk et. al14).

**Figure 2.** Ten question pre-test, post-test, and 6-months post-test assessment for iatrogenic endoscopic perforations, a quality improvement study in the GI lab.

**Figure 3.** Panel A: Clinical scenario #1 showing perforation after endoscopic mucosal resection at the gastric cardia.

Panel B: Clinical scenario #2 showing perforation (target sign) after endoscopic mucosal resection in the duodenal bulb.

**Figure 4.** Panel A and B show the pre-, post-test, and 6-months post-assessment accuracies per
question for fellows and practicing gastroenterologists, respectively.

**Figure 5.** Accuracies for clinical scenario #1 (panel A) and clinical scenario #2 (panel B) comparing fellows (magenta) and practicing gastroenterologists (green).
**Supplementary Figures Legends:**

**Supplementary Figure 1.** Needle decompression kit located in the supply room in a cabinet labelled “Emergency Supply”.

**Supplementary Figure 2.** Contents of the needle decompression kit.

**Supplementary Figure 3.** Procedural resource binder is found in each of our procedure rooms and contains important information for easy reference.

**Supplementary Figure 4.** The AIEP management algorithm is now located in the procedure binder and labelled with an orange tab for easy reference.

**Supplementary Figure 5.** Standardized one-page material given after pre-test.
Table: Demographics for the physicians participating in the assessments.

<table>
<thead>
<tr>
<th>Demographics</th>
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<tr>
<td>Physician, n (%)</td>
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<td>Practicing gastroenterologists</td>
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<td>Fellows</td>
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<td>Gender, n (%)</td>
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<td>Female</td>
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<td>Age, median years (IQR)</td>
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<td>Experience, median years (IQR)</td>
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<tr>
<td>Previous AIEP experience, n (%)</td>
<td>10 (36)</td>
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</tbody>
</table>
Clinical scenario #1

A 65 years old male with gastric duodenal ulcer is undergoing endoscopic mucosal resection with a hot snare. You see the following:

1. Is this an iatrogenic perforation?
   - Yes
   - No

2. What should you do immediately? (Check all that apply)
   - Stenting
   - Examining the intraperitoneal CO2 insufflation to ensure there is no air in the peritoneal cavity
   - Closing
   - Knitting
   - Suturing

3. Would you consider endoscopic closure?
   - Yes
   - No

4. If you answered yes, what would you consider for closure? (Check all that apply)
   - Through the scope clip (Omnifit)
   - Over-the-scope clip (Angioseal)
   - Suturing
   - Snare placement
   - None of the above

5. Would you consider an intra-procedural consult with interventional radiology?
   - Yes
   - No

6. If the abdomen is extremely distended due to excessive intraperitoneal gas, what would you consider doing? (Choose the best answer)
   - Decompression with an 18 or 20 gauge percutaneous needle
   - Reconsidering the percutaneous approach
   - Suction

7. Non-urgent tube placement is likely to be beneficial.
   - True
   - False

8. Would you consider starting the patient on antibiotics?
   - Yes
   - No

9. Would you consider a surgical consult?
   - Yes
   - No

Clinical scenario #2

A 65 years old male with duodenal bulb neuroendocrine tumor with the following finding during endoscopy. You immediately identify this as an AIEP based on the target sign, and you close it endoscopically with an over-the-scope clip.

You ordered a CT scan with water-soluble contrast, choose the best answers based on the following:

1. No leak was found, what is the next step? (Check all that apply)
   - Continue conservative management
   - CT-guided drainage
   - Surgical repair

2. A small contained leak was found, what is the next step? (Check all that apply)
   - Continue conservative management
   - Consult surgery
   - CT-guided drainage

3. A large or uncontained leak was found, what is the next step? (Check all that apply)
   - Continue conservative management
   - CT-guided drainage
   - Surgical repair
NEEDLE DECOMPRESSION
PLEASE RESTOCK AFTER EACH USE

(2) 60ML SYRINGES
(3) 18GA 1.88" NEEDLES (REF 381447)
(3) 20GA 1-3/4" NEEDLES (REF 4059)
(2) MONITORING LINES (REF MX564)
(2) 3-WAY STOPCOCK (REF MX4311L)
(2) 20GA X 2" IV CATH
PROCEDURAL
RESOURCE
BOOK
ROOM 6
Cedars-Sinai GI Perforation Guideline

Suction fluid and air
Make sure CO2 insufflation is on and set as low as possible
Attempt endoscopic repair if possible
Consider intraoperative consult with interventional endoscopy

If abdomen is distended due to excessive intraperitoneal free air, consider decompression with an 18 or 20 gauge percutaneous needle
**Kit is located in supplies room**

Consider NG tube placement

Consider Ceftriaxone 1g IV every 24 hours and Flagyl 500mg IV every 8 hours or Levofoxacin 750mg IV every 24 hours and Flagyl 500mg IV every 8 hours (Available in GI lab)

Consider CBC, BMP, LFTs, blood cultures, lactate, amylase, lipase, INR, EKG

Consider Consulting Acute Care Surgery/Colorectal Surgery

Admit patient to monitored bed or higher acuity

Consider CT chest, abdomen, pelvis with oral/NG/rectal water soluble contrast (ext. 3-1723)

If no leak, continue conservative management

If small contained leak, consider:
- Continue conservative management
- CT-guided drainage
- Surgical repair

If large or uncontained leak, consider Surgical Repair
Detailed Information on Iatrogenic Perforations

- **Early signs** of endoscopic perforation includes subcutaneous air/crepitus, abdominal distension, difficulty maintaining insufflation,
- **Late signs** of perforation include hemodynamic instability
- In a colonoscopy,
  - The most common site of perforation is in the sigmoid colon (53-65%) from mechanical trauma (i.e. direct trauma from scope, torque, retroflexion)
  - The second most common site of perforation is the cecum (14-24%) from endoscopic resection or dissection.
  - Look for the “target sign” after EMR, which is a white-gray center consisting of the muscularis propria surrounded by blue (indigo carmine/methylene blue stained submucosa), indicating partial/full thickness resection
- In upper endoscopy, ASGE recognizes the following as risk factors for perforation: anterior cervical osteophytes, Zenker’s diverticulum, esophageal strictures, malignancies, and duodenal diverticula
- The highest risk for perforation in therapeutic upper endoscopy is
  - dilation of complex strictures (caustic, radiation, malignancy), up to 17% risk of perforation
  - Risk of perforation for other therapeutic maneuvers: EMR 5%, ESD 6%, dilation of peptic ulcer strictures 0.1-4%, foreign body removal 0.8%, variceal sclerotherapy 5%
  - Variceal band ligation is rare (usually associated with overtube placement)
- The use of carbon dioxide insufflation rather than air insufflation may minimize the amount of extraluminal air because carbon dioxide is rapidly absorbed
- Extraluminal air can dissect into distant spaces and can lead to a medical emergency (i.e. tension pneumothorax, tension pneumomediastinum, abdominal compartment syndrome)
  - Immediate treatment with decompression needle is recommended
- Extraluminal air can persist for a few days to a week despite successful closure of a perforation. Correlate with the patient’s clinical condition.
- **CT scan with oral soluble contrast** has the highest sensitivity for diagnosing perforations
  - If there is oral contrast extravasation on CT scan, then the perforation persists, and requires immediate management
- When a perforation is diagnosed during an endoscopic procedure, suction the area avoiding leakage of fluid into the peritoneum, ensure CO2 insufflation, and try to close the perforation endoscopically
  - ESGE recommends through the scope (TTS) clips for perforation defects < 10mm. Those over 10mm, ESGE recommends over the scope (OTS) clips, omental patching, or combined technique of endoloop and TTS clips
  - A 2015 meta-analysis of 24 studies published in GIE revealed **89.9% successful endoscopic closure of an iatrogenic perforation**
- **NG tube placement** is recommended in patients with upper GI perforations to reduce the volume of gastric contents
  - For esophageal perforations, especially recommend NG tube placement endoscopically rather than blind insertion
- Antibiotics are recommended after a perforation occurs. Antibiotics should cover gram negative organisms, anaerobes, and gram positive streptococci. At Cedars-Sinai, the recommended antibiotic regimen is **ceftriaxone and flagyl**. In patients with penicillin allergy, levoflaxacin can be used instead of ceftriaxone. In high-risk patients (advanced age, poor nutritional status, presence of organ failure, immunocompromised), Zosyn is recommended.
  - Duration of antibiotics should be for 3-5 days if clinically stable
Cedars-Sinai GI Perforation Algorithm

Limit leakage into perforation by suctioning fluid and air
Consider re-positioning the patient
Make sure CO2 insufflation is on and set as low as possible

Strongly consider endoscopic closure* AND/OR
Strongly consider intraprocedural consult with interventional endoscopy

If abdomen is distended due to excessive intraperitoneal free air, consider decompression with an 18 or 20 gauge percutaneous needle (Kit is located in procedural supplies room in cabinet labelled “Emergency Supply” with the box labelled “Decompression Needle”)

Consider NG tube placement

Consider ceftriaxone 1g IV every 24 hours and metronidazole 500mg IV every 8 hours or levofloxacin 750mg IV every 24 hours and metronidazole 500mg IV every 8 hours (Available in GI lab)

Consider CBC, BMP, LFTs, blood cultures, lactate, amylase, lipase, INR, EKG

Consider consulting acute care surgery/colorectal surgery

Admit patient to monitored bed or higher acuity

Consider CT chest, abdomen, pelvis with oral/NG/rectal water-soluble contrast (Ext. 3-XXXX)

If no leak, continue conservative management

If small contained leak, consider:
- Continue conservative management
- CT-guided drainage
- Surgical repair

If large or uncontained leak, consider surgical repair

*Endoscopic closure:
Through-the-scope clips (≤10mm)
Over-the-scope clips (≤20mm)
Suturing
Stent placement
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. Dilatation

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