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Minimally invasive acute care surgery

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The importance of minimally invasive surgery techniques in acute care surgery

The use of minimally invasive surgery (MIS) techniques, including laparoscopy, robotics, and therapeutic endoscopy, has demonstrated safety and improved outcomes in many elective scenarios. These techniques have increasingly been applied to the management of acute care surgery conditions over the last couple of decades[1–4] (Fig 1). Acute care surgery encompasses both surgical management of trauma and emergency general surgery (EGS). EGS constitutes a significant and growing portion of inpatient admissions in the United States and approximately 30% of EGS patients ultimately undergo surgical intervention.[5,6] MIS techniques in EGS cases are associated with improved outcomes that include decreased rates of complications, reoperation, readmission, length of stay, and mortality.[1,7] MIS approaches also offer patients a faster recovery, decreased postoperative pain, earlier return to work, earlier resumption of normal daily activities, and cosmetic benefits.[2] Additionally, MIS approaches, in many cases, can provide better visualization of the entire abdominal cavity without increasing the surgically-induced trauma.[8]

However, the use of minimally invasive techniques varies by disease process, patient factors, hospital resources, and the surgeon's technical expertise and comfort level.[2] In a 2014 survey, Italian surgeons estimated that 30% of abdominal emergency cases were routinely managed by laparoscopy.[9] The most common reported cause of the inability to complete a procedure laparoscopically was unclear anatomy, while intra-abdominal bleeding was the most frequent intraoperative complication that induced a conversion to open.

Although some of the improved outcomes with MIS approaches are likely influenced by patient comorbidities and disease severity that cannot be fully adjusted for in statistical analyses, there are also conceptual biologic explanations for the findings. Stress response to surgery is decreased and postoperative immune function is improved in laparoscopy.[2] Patients may have improved ability to heal after laparoscopy due to decreased surgical trauma, especially in septic patients.[10]

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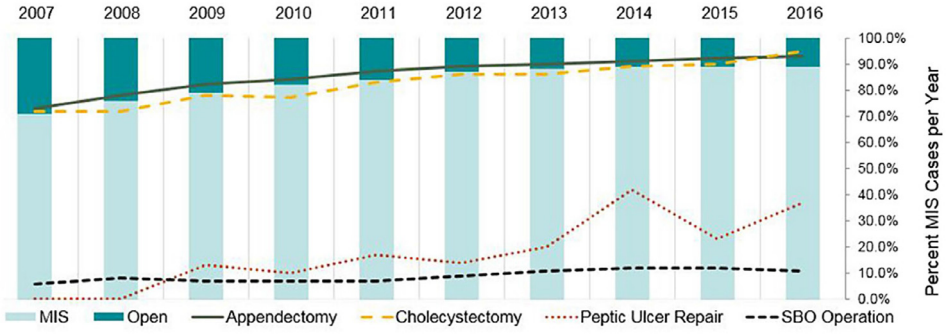


Fig. 1. Utilization of minimally invasive techniques for emergency general surgery. Color version of figure is available online.

Yet, despite these benefits, the MIS approach for acute care surgery is not universally applied and it can be associated with certain pitfalls. Depending on the hospital resources and attitudes, there may be a lack of accessibility of equipment and personnel, especially in the non-elective setting.[3] Additionally, there is a need for communication with anesthesia providers regarding patient hemodynamic status, insufflation, and potential indicators of a need to convert to an open approach. It is also possible for a surgeon to persist in attempts at an MIS approach past the point of futility, however it is often difficult to pinpoint exactly when conversion to an open approach would be best for the patient. It is important for specific patient factors to be assessed and addressed before embarking on the MIS approach. If these factors are not recognized, it can create a situation of greater harm. Finally, with the narrow visualization of a laparoscope, the entire abdominal cavity will only be thoroughly explored if this is done intentionally and systematically.[4] Ultimately, the guardrails around the use of MIS approaches in acute care surgery should be the same as they are for the use of MIS in elective procedures. Furthermore, any MIS procedure should be performed as safely and effectively as with traditional open surgery.[2]

The clinical essentials of laparoscopy

The Fundamentals of Laparoscopic Surgery (FLS) course teaches the basics of the laparoscopic technique. This includes topics such as gaining entry to the abdomen to establish a pneumoperitoneum and will not be discussed in detail here. The following are some tips the authors feel can help with more complex patients.

For abdominal explorations, the authors recommend that at least 4 ports be used to perform a thorough evaluation. Larger, obese patients and abdomens with previous surgery will often need additional ports to help with retraction. The surgical team should be prepared to visualize all of the areas of the abdomen and to do so, the patient will be placed in Trendelenburg, reverse Trendelenburg, left side up, and right side up positions during the exploration. To prevent patient movement on the operating room (OR) table and potential patient falls, 2 straps should be placed around the patient's lower extremities securing the patient to the table. For larger patients, an upper body strap should be considered. A foot board should be placed. To facilitate the surgeon being able to operate on the patient in Trendelenburg position, the patient's upper extremities should be tucked. An orogastric tube should be placed to make it easier to manipulate the stomach and to improve visualization in the upper abdomen.

The height of the table should be adjusted such that the surgeon's shoulders do not need to be raised to perform maneuvers. This will lead to fatigue and will compromise accuracy. The surgeon's arms should be able to rest comfortably at the side with the elbows bent less than 90°. To facilitate this, the table can be lowered and the surgeon can stand on a stepstool. For obese

patients, the pneumoperitoneum can significantly elevate the abdominal wall and surgeons may need to stand on 2 stools to operate properly.

For cases that typically require 3 ports (appendectomy) or 4 ports (cholecystectomy), the acute pathology can make it difficult to obtain adequate visualization. The need to convert to an open procedure can sometimes be overcome by adding ports to assist with obtaining the necessary visualization. For example, during a complicated cholecystectomy in an obese patient with a large fatty liver, a port may be required to retract the liver and another one to retract the omentum, so that the gallbladder can be seen. In general, there is no increased morbidity or surgical stress response with the addition of more ports, while the advantages of laparoscopy remain even with these additional ports.

It may be difficult to obtain proper visualization in patients that have diffuse peritonitis. This is partially due to the abdominal wall musculature contracting ("guarding") causing increased intra-abdominal pressure. The insufflation pressure is typically set at approximately 12 - 15 mm Hg. Thus, the maximum pressure can be reached before adequate visualization is achieved. To assist with improving visualization via insufflation, the anesthesia team should make sure the patient is completely relaxed. The suctioning of pus or luminal contents should decrease peritoneal irritation and allow the abdominal wall to relax, allowing for a more adequate pneumoperitoneum once the irritating contents are removed.

In patients with previous abdominal operations, even laparoscopic ones, the initial entry should be several centimeters away from previous incisions. Even though the possibility of herniation increases with port sizes of 10 mm or more,[11] adhesions can occur at any port site. Consequently, the initial entry should not go through a previous incision, even if it is a small, 5 mm incision. After abdominal access is gained, adhesions can be taken down as needed, allowing proper visualization. For previous midline incisions, the authors recommend using an open Hasson technique, at least 5 cm from the midline incision, to gain initial entry into the abdomen. However, sometimes this is not possible, in which case a Hasson technique in the midline or a Veress needle approach through Palmer's point are acceptable options.

If the patient has had a previous hernia repair with mesh, it may be difficult to find a port position that does not violate the mesh, regardless in which layer the mesh lays. If the mesh was placed intraperitoneally, there are likely to be adhesions.[12] When possible, it is advised to gain pneumoperitoneum and first port placement far from where the mesh is located to avoid these adhesions. Subsequent port placement should be guided by the laparoscope to avoid injury to the mesh when possible.

In patients with a previous abdominoplasty, in addition to adhesions, visualization may be compromised by the lack of compliance in the abdominal wall. There is not much one can do to improve this situation except recognize that this is happening, in an effort to reduce the frustration related to not obtaining the desired visualization.

The decision to persist via a laparoscopic technique ultimately depends on the surgeon's skill and comfort with performing the procedures. The authors believe that simulation practice of laparoscopic and endoscopic skills and the use of different instruments can greatly enhance a surgeon's abilities. This includes the use of robot-assisted laparoscopy. With the proper direction and some practice, the techniques described in this monograph can be part of the acute care surgeon's practice; and this is likely to improve the outcomes in these patients.

Acute care diseases and the MIS approach

MIS in appendicitis

Acute appendicitis was the first EGS diagnosis in which there was widespread acceptance of the utilization of MIS techniques. The first laparoscopic appendectomy was performed in 1983 by Professor Kurt Semm at the University of Kiel. As early as 1992, case cohort studies demonstrated the benefits of laparoscopy in reducing postoperative pain and improved recovery, but

especially in the early days of uptake this approach was associated with increased operative time.[13] The current understanding of the benefits of the laparoscopic approach for appendicitis is based upon robust literature and guidelines.

Uncomplicated appendicitis

In 2009, the Society of Advanced Gastrointestinal and Endoscopic Surgery (SAGES) published a guideline stating that laparoscopic appendectomy was a safe and effective method for treatment of uncomplicated appendicitis.[14] In a more recent "summary of guidelines" by the American Association for the Surgery of Trauma (AAST), laparoscopic appendectomy was described as the gold standard for acute appendicitis, and the authors stated that it "should be the procedure of choice, except when laparoscopy is contraindicated or not feasible."[15] The 2016 World Society of Emergency Surgery (WSES) Guidelines also concluded that laparoscopic appendectomy should "represent the first choice where laparoscopic equipment and skill are available." Notably, the laparoscopic appendectomy is specifically outlined as being safe in specific populations (obese, elderly, pediatric, and pregnant patients),[14,15] although the 2016 WSES Guidelines were more equivocal in the pregnant patient population. Since the early case-control studies, more recent meta-analyses continue to show that laparoscopic appendectomy is associated with shorter hospital stays, quicker return to full activities, and lower wound infection rates.[14,16] Although the laparoscopic approach was initially associated with increased rates of deep pelvic abscesses, this is no longer the case in more recent studies, which suggests that, with added experience, the rate of abscess formation is decreased.[14,16] In a recent multicenter study of patents with appendicitis, 90% had computed tomography (CT) imaging, 98% of operations were performed utilizing laparoscopic techniques, and the median hospital length of stay was 1 day.[17] Conversion to open operation is generally rare, although reported rates vary from 0% to 27%.[14,17]

Stump closure

There are many options for appendiceal stump closure in the laparoscopic approach, including endoscopic staplers, the endoloop technique, and polymeric ligating clips (Fig 2).[18] There have been no definitive studies demonstrating a difference in clinical outcomes between the use of endoscopic staplers and endoloops.[15,16] There are differences in terms of supply cost, operative time, and learning curve for each of these options and local resources and expertise are critical to selecting the best option for stump closure.[2,18]

Mesenteric vascular control

Similar to stump closure, there are many options for control of the vascular supply to the appendix: monopolar electrocoagulation, bipolar energy, metal or polymeric clips, endoloops, endoscopic staplers, and vessel sealing devices. Both the WSES Guidelines and AAST EGS Guideline Summary note that that there are no clinical differences between the techniques. The WSES Guidelines specifically note that monopolar electrocoagulation and bipolar energy are the most cost-effective but also require more experience to avoid complications such as bleeding or thermal injuries.[2,15]

Perforated appendicitis

Despite the increased complexity, laparoscopy has been demonstrated to be safe and feasible in patients with perforated appendicitis[14] and to have lower overall costs compared to open surgery.[16] Compared to non-complicated appendicitis, surgical procedures in patients with perforated and gangrenous appendicitis had longer operative duration and more frequent drain utilization.[17] Although irrigation is often used in open contaminated cases, the benefits of peritoneal irrigation in acute appendicitis are less clear. Peritoneal irrigation was not identified to have any advantages over suction alone in complicated appendicitis.[16]

Frontiers

Although laparoscopic appendectomy is possibly the most widespread use of MIS in EGS, it is not without controversy. In patients with significant past surgical history, obtaining access

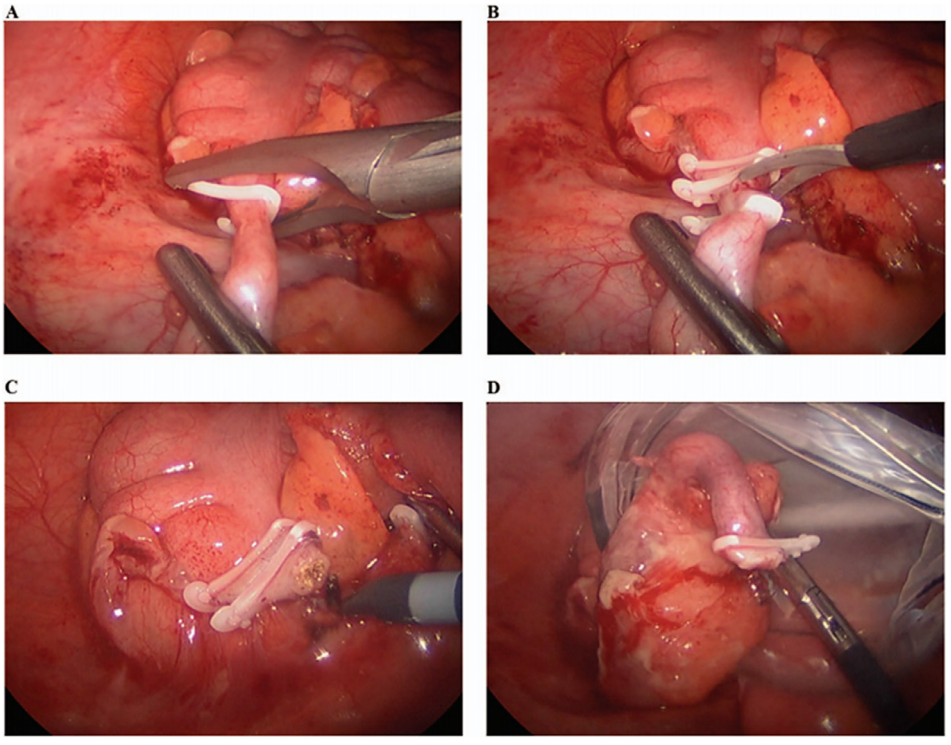


Fig. 2. (A) Placement of polymeric clip on appendiceal base. (B) Scissor ligation of appendix after placement of 3 polymeric lips. (C) Electrosurgical fulguration of appendiceal stump mucosa with 2 polymeric clips secured. (D) Inflamed appendix placed into specimen bag for removal. Credit to both the Journal of the Society of Laparoscopic Surgeons and the Society of Laparoscopic & Robotic Surgeons (SLS). Color version of figure is available online.

to the abdominal cavity can be challenging. In patients with other surgical diagnoses (such as complex incisional hernia), the goal at the time of appendectomy for acute appendicitis is to treat the urgent issue and most often it is best to avoid definitive management of other chronic issues. Finally, there are multiple methods to safely perform laparoscopic appendectomy, and continued efforts to identify more cost-effective and time-saving techniques will further increase the benefit of a minimally invasive appendectomy.

MIS in biliary disease

Cholecystitis

For the remainder of the acute care diseases, there are no society statements on the use of MIS techniques as the first choice of surgical approach. However, to varying degrees, MIS techniques are considered the first option, as is the case in patients with acute cholecystitis. The diagnosis of acute gallstone cholecystitis can often be made quickly with readily available ultrasonography (US). If a question about the diagnosis remains, then a nuclear medicine hepatobiliary iminodiacetic acid (HIDA) scan can be performed. Non-filling of the gallbladder on a HIDA scan confirms the diagnosis of cholecystitis. In the case of acalculous cholecystitis, the diagnosis should be suspected based on a clinical history of critical illness (prolonged intubation, prolonged non-enteral feeding, etc.) and confirmed by a HIDA scan. Typically, these patients are too fragile or unstable to undergo surgery and instead have a percutaneous cholecystostomy tube placed. Here, we focus on gallstone induced acute cholecystitis.

A distinction is often made between acute cholecystitis and symptomatic cholelithiasis. Patients with symptomatic cholelithiasis do not have active gallbladder inflammation and can be discharged from the emergency room and scheduled for an elective procedure. However, the two disease processes often have similar presentations and the distinction between the 2 can be subtle. Obesity can further obscure physical examination findings, making the diagnosis of acute cholecystitis more difficult. Even in electively scheduled cholecystectomies for presumed symptomatic cholelithiasis, surgeons will often find an inflamed gallbladder that is difficult to dissect. With nonoperative observation of patients with biliary colic there is an increased risk of gallstone complications (mainly acute cholecystitis) and surgical complications, albeit minor.[19] Additionally, there is an 18% chance of a recurrent episode or a worse episode within 6 weeks of the primary event.[20] This information indicates that surgery should be performed in patients with symptomatic cholelithiasis as a priority, even on an outpatient basis.

Once the diagnosis of acute cholecystitis is confirmed, the next step is deciding when to proceed with surgery. At the turn of the 21st century, there was a debate on whether earlier intervention at less than 72 hours was better than a cooling off period of 6-8 weeks that would allow for a resolution of inflammation and potentially offer a less difficult laparoscopic dissection. Perhaps in part due to the improvements in technique and education over the past 2 decades, recently published evidence indicates that earlier intervention is associated with decreased length of hospital stay, decreased wound infections, and increased cost-effectiveness.[20,21] Importantly, earlier intervention is not associated with increased mortality, bile duct injury, bile leaks, or conversion rates.

Patients with suspected acute cholecystitis should also be evaluated for choledocholithiasis along with its possible sequelae, cholangitis and pancreatitis. Findings that should raise the concern for choledocholithiasis include jaundice, elevated total bilirubin, dilated common bile duct, stone disease noted on US, and/or elevated serum lipase. In cases of clinical uncertainty, a magnetic resonance cholangiopancreatography (MRCP) can be performed to confirm the diagnosis. If MRCP or US confirms the presence of choledocholithiasis or the suspicion is high for choledocholithiasis based on laboratory values, initial management can be accomplished by endoscopic retrograde cholangiopancreatography (ERCP) in the endoscopy suite or in the OR in conjunction with a laparoscopic cholecystectomy. If the patient presents with cholangitis and sepsis, then immediate decompression of the common bile duct (CBD) is warranted.

When an ERCP is performed as the initial management, a sphincterotomy and stent placement are often utilized to facilitate continued flow into the duodenum. Subsequent cholecystectomy can be performed the next day. If the cholecystectomy is performed initially in patients with concern for choledocholithiasis, it should be done in conjunction with an intraoperative cholangiogram. If the cholangiogram is negative, then a CBD exploration is not needed. On the other hand, if there is a filling defect then the options include performing a laparoscopic CBD exploration, an open CBD exploration, or to schedule an ERCP postoperatively for the next day (when available).

Increasingly, there are reports and data regarding performing ERCP and cholecystectomy under the same anesthesic.[22,23] In this scenario, the ERCP is performed first, then the patient is repositioned (if needed) for a cholecystectomy. This technique has several advantages. It is more cost-effective, it prevents a second anesthetic for the patient, and it decreases the hospital length of stay. Additionally, if the ERCP cannot be accomplished for technical reasons, the surgeon is aware of this and knows that CBD exploration will be needed. There are also published reports of a rendezvous procedure in which the surgeon passes a guide wire down the CBD that the endoscopist can use to perform the ERCP.[24,25]

Laparoscopic cholecystectomy technique in difficult cases

Several factors can increase the difficulty level of laparoscopic cholecystectomy. The severity of the cholecystitis can be predicted by either of 2 grading systems: the Tokyo guidelines (Table 1) or the AAST-EGS severity grading scale (Table 2).[26,27] Previous abdominal surgery, especially in the upper half of the abdomen, can further increase the technical difficulty. Often, adhesiolysis would still be required if an open approach was used. Extra ports may need to be

Table 1
Tokyo guidelines for cholecystitis severity.

Classification	Description
Grade I: Mild	Cholecystitis in a healthy patient with mild inflammatory changes and no organ dysfunction
Grade II: Moderate	Cholecystitis with any of the following: WBC > 18K Duration of symptoms > 72 h Palpable tender mass in RUQ Signs of local inflammation: Gangrenous cholecystitis Bile peritonitis Hepatic abscess Pericholecystic abscess Emphysematous cholecystitis
Grade III: Severe	Cholecystitis with organ dysfunction: Cardiovascular – hypotension requiring pressor support Neurologic – decreased level of consciousness Respiratory – p_aO_2/F_iO_2 < 300 Renal – oliguria or creatinine > 2.0 mg/dL Hepatic - INR > 1.5 Hematologic - platelets < 100K

From Yokoe M, Hata J, Takada T, Strasberg SM, Asbun HJ, Wakabayashi G, Kozaka K, Endo I, Deziel DJ, Miura F, Okamoto K. Tokyo Guidelines 2018: Diagnostic criteria and severity grading of acute cholecystitis (with videos). Journal of Hepato-biliary-pancreatic Sciences. 2018 Jan;25(1):41-54. RUQ, right upper quadrant; INR, international normalized ratio.

Table 2
American Association for the Surgery of Trauma (AAST) emergency general surgery (EGS) severity score.

Grade	Description	Proposed Management
I	Local disease, minimal abnormality	Surgery if <10 d of onset, consider PC if > 10 d
II	Local disease, severe abnormality	Surgery, can consider PC and antibiotics
III*	Beyond the organ, locally advanced only	Surgery
IV*	Beyond the organ, regional advanced	Surgery
V*	Beyond the organ, systemically advanced	Surgery

PC, percutaneous cholecystostomy.
Modified from Schuster KM, Holena DN, Salim A, Savage S, Crandall M. American Association for the Surgery of Trauma emergency general surgery guideline summaries 2018: Acute appendicitis, acute cholecystitis, acute diverticulitis, acute pancreatitis, and small bowel obstruction. *Trauma Surg Acute Care Open.* 2019;4:e000281.
* Percutaneous drainage and antibiotics can be considered in patients who are unfit for emergency surgery due to their comorbidities.

placed to take down the adhesions and clear the anterior abdominal wall before placing the standard ports for cholecystectomy. When taking down any intestines that are adherent to the anterior abdominal wall, the pneumoperitoneum can aid in retraction, making adhesions easier to identify. The authors recommend using sharp dissection to reduce the chance of an energy related injury. Small enterotomies can be repaired laparoscopically with 1 or 2 sutures, again similar to the open approach.

In patients who are morbidly obese, additional ports may be needed for retraction of intraperitoneal fat. Additionally, a fatty liver from obesity may be large and hard to mobilize, making it difficult to retract the fundus of the gallbladder over the liver. The authors recommend a liver retractor, such as the Nathanson retractor, that can be used to retract the liver safely. Similar retractors can also be used to push the omentum, duodenum, and colon posteriorly or inferiorly to improve access to the cystic triangle.

When the anatomy cannot be delineated clearly, an intraoperative cholangiogram can be performed to further identify critical structures. The Cook catheters require placement into the cys-

Table 3
Trans-cystic and trans-choledochal common bile duct exploration.

	Trans-cystic	Trans-choledochal
Stone size	<6 mm	>6 mm
Cystic duct size	>4 mm	<4 mm
Common bile duct size	<6 mm	>6 mm
Intrahepatic stones	-	+
Cystic duct position	Lateral	Lateral, posterior, or distal

Adapted from lecture by Sara Hennessey, MD, at MIS Masters Course at the Eastern Association for the Surgery of Trauma, January 14, 2020.

tic duct, which is occasionally challenging when the cystic duct cannot be identified. The Kumar clamp allows the cholangiogram catheter to be placed into the infundibulum and neck of the gallbladder. Immunofluorescence is another option used to help identify the extrahepatic biliary anatomy. This does require the camera to have near-infrared light visualization. Indocyanine green (ICG) can be administered preoperatively to help identify the biliary tree without radiographic support. The ICG takes approximately 30 minutes after peripheral venous injection to reach the biliary system.

Regardless of the challenges encountered, the infundibulum and the cystic triangle must be identified so the surgeon can dissect out the triangle of Calot and achieve the critical view of safety to perform a complete cholecystectomy. If the critical view of safety cannot be achieved, then a subtotal cholecystectomy should be performed. The remaining gallbladder does not need to be sewn shut and instead should be left open (fenestrated approach). The mucosa is treated with monopolar energy on the coagulation setting to prevent secretions from the residual cuff of gallbladder. A drain should also be placed in case a bile leak occurs. The bile should preferentially drain through the CBD into the duodenum rather than through the fibrosed, inflamed, and often occluded (in the case of acute cholecystitis) cystic duct. Postoperatively, if bile drainage is continuous or copious (as measured by drain output), then a distal CBD obstruction may be present. The drain should be kept in place and an ERCP should be performed to ensure there is no obstruction or bile duct injury. Further treatment could include a stent or sphincterotomy during ERCP so that flow would further be favored into the duodenum.[28]

In patients with previously undiagnosed severe cirrhosis or who become hemodynamically unstable during the procedure (other than intraoperative bleeding), then a laparoscopic cholecystostomy tube can be placed to decompress the gallbladder and control the infectious process. A hole is made in the body of the gallbladder using surgical energy. The authors prefer placement of a balloon catheter, such as a Foley urinary catheter, through one of the working ports or through a separate incision such that the drain is not placed on tension. When the patient is stable, the patient can return to the OR for removal of the gallbladder, typically after several weeks of recovery.

Choledocholithiasis and the laparoscopic common bile duct exploration

Laparoscopic common bile duct exploration (LCBDE) is indicated when there are retained stones in the CBD seen on intraoperative cholangiogram or when identified preoperatively but were unable to be removed via ERCP. There are 2 described approaches to the LCBDE: trans-cystic and trans-choledochal. Acute care surgeons should be familiar with both techniques as they are a valuable addition to their armamentarium. The most important step is preoperative preparation if the surgeon thinks they will likely need to perform one. A LCBDE requires a catheter, a guidewire, a balloon dilator, a choledochoscope, saline flush, and a retrieval basket.

Table 3 describes when a surgeon should use the trans-cystic or trans-choledochal approach. For the trans-choledochal approach, the additional step of placing stay sutures at the 3 and 9 o'clock positions of the common bile ductotomy is needed. The steps of the LCBDE, regardless of the trans-cystic or trans-choledochal approach, are summarized in Table 4.

Table 4
Technical steps of laparoscopic common bile duct (CBD) exploration.

1. Place cholangiogram catheter in duct. A trans-cystic suture for retraction can be used to help guide the catheter into the duct. Sometimes a separate incision in the abdominal wall is needed for the cholangiogram catheter so that more direct access into the duct can be achieved.
2. Perform cholangiogram to evaluate for a filling defect or meniscus sign that indicates a stone or stones are present.
3. Give 2g glucagon intravenously.
4. Place wire through cholangiogram catheter and advance into distal CBD or duodenum. Fluoroscopic guidance can be helpful here.
5. Remove cholangiogram catheter, leaving the wire in place, place balloon dilator over the wire, and use an inflated balloon to dilate the cystic duct or CBD.
6. Remove balloon dilator, leaving wire in place.
7. Place choledochoscope into duct using the guidewire. Remove wire.
8. Examine distal common bile duct and, if possible, advance scope into duodenum. This will require continuous flushing of the choledochoscope via a 1 L saline bag connected to the choledochoscope.
9. If a stone is seen, place basket retrieval device through choledochoscope into the CBD to retrieve the stone. With the stone in the basket, remove both the choledochoscope and the basket together. A basket with a stone in it will not go through the choledochoscope channel. Of note, balloon catheters (even a small 2Fr Fogarty one) will not be able to be placed through the choledochoscope.
10. Replace cholangiogram catheter and repeat cholangiogram. Repeat, as needed, until no residual stones are identified.

Summary

In summary, removing the acute gallbladder is one of the most common procedures performed by surgeons who cover EGS patients. The surgeon can anticipate a higher level of difficulty with the presence of obesity, previous abdominal surgery, and a higher Tokyo class or severity on the AAST-EGS grading scale. If the critical view of safety cannot be achieved, then a subtotal cholecystectomy should be performed. Acute care surgeons should add LCBDE to their skillset and be ready to perform this procedure using both the trans-cystic and trans-choledochal approaches.

MIS in peptic ulcer disease

The incidence of peptic ulcer disease (PUD) and its complications has decreased dramatically over the 21st century.[29] The most common complications necessitating surgical evaluation are perforation and bleeding, and less often pain and gastric outlet obstruction symptoms (nausea and vomiting). PUD accounts for 40%-60% of all upper gastrointestinal (GI) bleeding and is the most common etiology of upper GI perforation.[29]

Bleeding peptic ulcer disease

Management of the patient with a bleeding peptic ulcer will typically follow the guidelines for general management of GI bleeding, focusing on resuscitation, reversal of any coagulopathy, and evaluation for a source. Excellent guidelines are available from the American College of Gastroenterology for initial management of GI bleeding (including lower gastrointestinal, small bowel, and peptic ulcer bleeds),[30] yet no national or societal guidelines exist for surgical management in this population. *Lagenbeck's Archives of Surgery* from 2000 includes an algorithm that focuses on endoscopic and surgical management.[31] Many institutions have their own guidelines for management of GI bleeding based on local resources and consensus. In general, it is recommended that endoscopic and radiologic means be used to stop the bleeding from ulcers unless the patient becomes hemodynamically unstable. This may involve multiple attempts of both modalities. Importantly, evaluation for malignancy as the cause of the ulcer must be considered.

Endoscopy. Once a GI bleeding episode has been determined to have an upper GI etiology (based on history, gastric lavage, and/or endoscopy), therapeutic endoscopy is recommended for

patients with active spurting, oozing bleeding, or a non-bleeding visible vessel and may be considered if there is an adherent clot resistant to vigorous irrigation.[32] Endoscopic therapies include epinephrine injection alone or in combination with either surgical energy treatment or clips. These are effective in achieving hemostasis in 85% - 92% of patients.[33]

Radiology. Although radiology often plays an important role in the localization of GI bleeds, it can also play a therapeutic role. Embolization of the gastroduodenal artery can often stop a bleed from PUD that is either too brisk to be managed by endoscopy or persists after endoscopic management. Although this interventional tool is rarely within the armamentarium of the surgeon, it is an important minimally invasive adjunct that should not be overlooked in the management of a bleeding peptic ulcer.

Laparoscopy. Although there are several case reports from the late 1990s exploring MIS as a management option for bleeding peptic ulcer disease,[34,35] we were unable to find more recent reports of this approach and do not currently use it in our practice. Surgical management most commonly involves suture ligation or gastric resection via an open approach.[31]

Perforated peptic ulcer disease

Perforated peptic ulcers are most commonly managed with surgical intervention. There remains the rare situation in which a perforated ulcer seals itself and is managed nonoperatively.[36] The outcomes of surgical management continue to improve, however, as the use of laparoscopy increases, making the benefit of nonoperative management increasingly small. Case series of successful laparoscopic repair have been available in the literature for more than 20 years.[37] Perforated peptic ulcers have been categorized based on size and this has been used to guide options for surgical management. Small ulcers are most commonly described as less than 2 cm, large ulcers from 2 - 3 cm, and giant ulcers larger than 3 cm.[38]

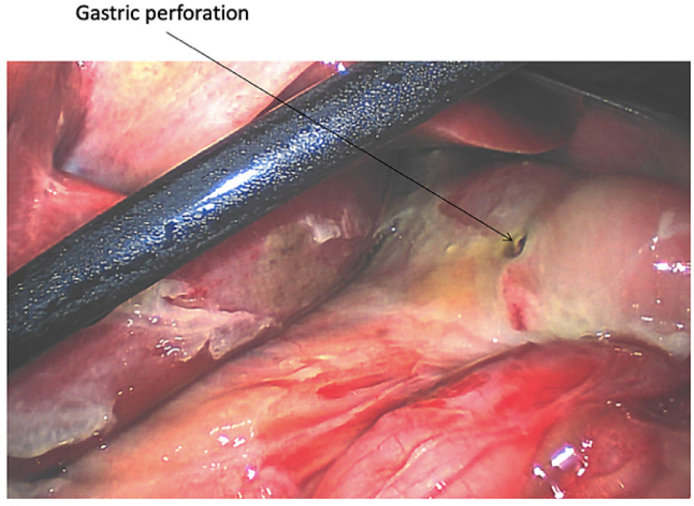
Laparoscopic repair for a benign peptic ulcer is the same as an open one, and a Graham patch is typically performed (Fig 3). The surgeon should spend time suctioning out the gastric contents as well; this may be necessary before enough room is created to place additional ports. Again, at least 4 ports are recommended to perform a thorough evaluation.

There are a number of studies reporting on outcomes of laparoscopic vs open repair in a case-cohort fashion, but are all limited in their ability to control for patient factors that may have influenced the decision to proceed in a laparoscopic fashion. In a recent systematic review of 7 randomized controlled trials comparing laparoscopic vs open repair for perforated peptic ulcer disease, laparoscopic repair was associated with overall decreased morbidity, wound infections, and shorter length of stay.[39] There was an increased incidence of leak in laparoscopic repair (1.1% vs 0.3%, OR 2.23, 95% CI 0.52-9.53), but this was not statistically significant. There remained a very low incidence of reoperation (1.1% in the laparoscopic repair group) and, in fact, the laparoscopic approach was associated with a lower incidence of intra-abdominal abscess.[39]

Despite these data, laparoscopic repair of PUD remains variable.[1,9] Areas in which the minimally invasive approach is standard continue to push the envelope to improve patient care, implementing enhanced recovery after surgery (ERAS) protocols within this patient population, including early removal of nasogastric tube and Foley catheters, multimodal pain medication, and early advancement of the diet.[40] Future work to standardize the management of patients with PUD and implement ERAS protocols will be valuable for improving patient outcomes in this disease.

MIS in pancreatitis

Pancreatitis is another disease for which there is a decided advantage with a minimally invasive approach, specifically in the setting of pancreatic necrosis and infected pancreatitis. Furthermore, there are accumulating data that show that the endoscopic therapies are superior to laparoscopic approaches.[41] Initial assessment of patients with pancreatitis should include disease severity and time course of disease. Mild pancreatitis is defined as pancreatitis associated with



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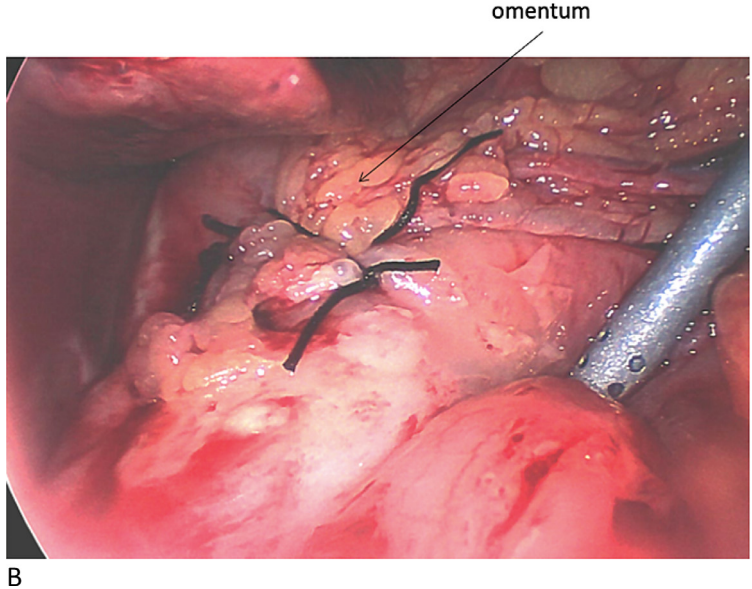


B

Fig. 3. Peptic ulcer disease. (A) 3 mm perforation in antrum of the stomach. (B) Graham patch repair. Color version of figure is available online.

only mild organ dysfunction. Moderate pancreatitis has multi-organ dysfunction and, by definition, will resolve within 48 hours, after which it can be managed the same as mild pancreatitis. Mild or moderate pancreatitis caused by gallstone disease is still best treated by cholecystectomy and either ERCP or CBD exploration. Initially, moderate pancreatitis that does not resolve after 48 hours is considered severe pancreatitis. Severe, infected pancreatic fluid collections, and walled off necrosis (WON) are best managed initially without surgery. Instead, a step-up approach is used (Fig 4).

Management depends on the timeframe of disease in addition to its severity. Most episodes of acute pancreatitis will resolve within 2 weeks (early pancreatitis) whereas episodes that per-

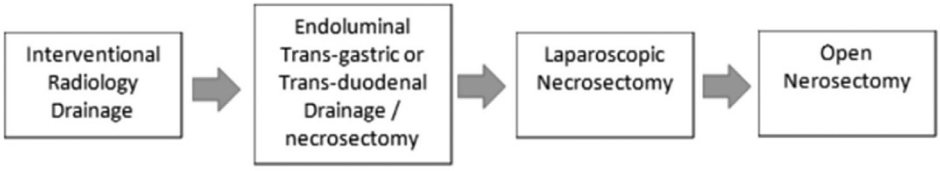


Fig. 4. Step-up approach for walled off pancreatic necrosis. Color version of figure is available online.

sist longer are labeled late pancreatitis. After the initial 2 weeks of early pancreatitis, a CT of the pancreas will often identify peripancreatic fluid or pancreatic necrosis. Immediate drainage is not indicated unless there is concern for infection, which should be suspected if there is air within the peripancreatic fluid collection. If infection is suspected, drainage at this point should be performed with radiologic guidance. If there is no infection, then a period of time of approximately 4 weeks should elapse before intervention is considered to allow for encapsulation that results in WON. The indications for intervention after 4 weeks include evidence of infection and ongoing symptoms attributed to WON. Common symptoms include abdominal pain, inability to tolerate oral intake, persistent fevers, and malaise.

The initial intervention for WON should also be percutaneous with radiologic guidance. Because this is unlikely to be sufficient to remove all of the infected or necrotic material, more extensive procedures are often required. Using the step-up approach described above, the next procedures of choice are endoscopic, if they are available. The endoscopic approach can include bare-metal stent placement into the WON and endoscopic necrosectomy. Endoscopic transluminal techniques may require endoscopic US to avoid vessels and to find WON that is not abutting the stomach or duodenum. Extensive necrosectomy can be accomplished endoscopically and this requires both advanced endoscopic skills and special equipment. The multiple transluminal gateway technique (MTGT) involves placing multiple stents with one of the stents connected to a catheter placed nasally that provides continuous irrigation. The authors report a 97% success rate in WON drainage vs 52% with a single stent.[42] Lumen opposing stents can also be deployed to perform necrosectomy and drainage. These tend to be wider and allow for immediate and mechanical necrosectomy. Their success, though, seems to be equivalent to the MTGT method.[43]

Laparoscopic approaches include both a traditional trans-abdominal laparoscopic approach or a video-assisted retroperitoneal dissection (VARD). The trans-abdominal laparoscopic approach can also include a trans-gastric approach in which the surgeon enters the abdomen, then opens the stomach anteriorly to access the WON through the posterior stomach wall.[44] The WON must be abutting the stomach in order for this to be successful. The VARD approach includes accessing the WON via a flank approach to the retroperitoneum, which has the advantage of avoiding the peritoneal cavity.[45] This may be the better approach if the WON is more lateral or does not involve the posterior stomach. Both the traditional laparoscopic and the VARD approaches will likely require multiple procedures.

The endoscopic and laparoscopic techniques both appear to be safe and neither has a greater risk of mortality. There does appear to be some advantage to utilizing endoscopic techniques first. Three meta-analyses show a benefit for the endoscopic approach, with decreased incidence of new-onset multiple organ failure, fewer pancreatic fistulae developed, and a shorter length of hospital stay.[41,46,47] There are, however, several advantages with the minimally invasive techniques over using open approaches. In a prospective randomized trial, when a MIS-first approach was employed and compared to an initial open necrosectomy, there was decreased incidence of organ failure, incisional hernias, and post-pancreatitis diabetes.[48] Furthermore, in retrospective analysis there is a 90-day survival advantage with MIS techniques over open surgery.[50] There also seems to be a long-term survival advantage several years after the event using the MIS approaches.[49,50] There is still a role for open necrosectomy, though, as patients who fail to respond to either MIS techniques or experience a complication such as bleeding from the MIS techniques, will likely require an open approach.[51]

Table 5
Progression of laparoscopic small bowel obstruction procedure.

Step	Description
1	Gain entry remotely from prior incisions and dilated bowel
2	Clear the anterior abdominal wall so that an adequate number of ports can be placed
3	Place enough ports (4-6) to perform a proper exploration:
4	Run the bowel from the terminal ileum, proximally
5	Bowel resection, internal hernia, ventral hernia repair, as indicated

What is understated in this discussion is that patients with severe pancreatitis are often very sick and with organ failure. Additionally, the mortality and morbidity remain high for those patients with severe pancreatitis, even with the use of MIS approaches.[52] Although the step-up approach is beneficial in treating acute pancreatitis, there is still a great need for care of the systemic complications of the pancreatitis. For the acute care surgeon, this means early operations should be avoided and a multidisciplinary approach should be utilized, including consultation with a hepatico-pancreatico-biliary surgeon and an advanced therapeutic endoscopist. Finally, if an advanced endoscopist or interventional radiologist is not available at the local hospital, then these complex patients often benefit from transfer to an institution where these resources are available.

MIS in small bowel obstruction

There can be little doubt that there is some benefit to approaching patients with a small bowel obstruction (SBO) with a laparoscopic technique. Most of the randomized trials show improvements in length of stay[53] and meta-analyses show decreased wound and non-surgical complications. At the same time, not every patient can be approached in this manner and some may fare better with either extended nonoperative management or an open approach. The laparoscopic approach is more likely to be successful when the previous surgery was performed laparoscopically, if a single adhesion or transition point is seen, if the patient has not had multiple open procedures, and there are not multiple hernia defects.[54] Here, we focus on obstructions caused by adhesive disease and will not address hernias or malignancies that manifest as bowel obstructions.

The operative plan of laparoscopy for bowel obstructions is outlined in Table 5. Gaining entry into the abdomen and establishing the pneumoperitoneum can be one of the most difficult tasks in this patient population. The authors recommend the Hasson open approach when doing so and making the initial entry several centimeters away from the previous incisions. Additionally, the surgeon should review the CT and identify where the dilated bowel is primarily located and avoid entry in that region when feasible. Adhesions are expected, so the initial dissection should clear the abdominal wall of adhesions so that other ports can be placed. The pneumoperitoneum itself is a retractor that may allow some of the omentum, adhesions, and intestines to fall dorsally, making the dissection easier.

When lysing adhesions or taking down omentum stuck to the anterior abdominal wall, the authors recommend sharp dissection to avoid injury from energy use. Injuries with sharp dissection are usually more readily seen, making them easier to find and repair. Additionally, they are safer to repair given the lack of thermal damage that may not be initially identifiable. If surgical energy is to be used, the authors recommend advanced bipolar sources, such as the LigaSure, that will limit direct activation and indirect coupling injuries that can occur with monopolar energy devices. Advanced bipolar devices also have limited residual heat, which is seen with ultrasonic devices and can create thermal injury if used to retract other tissues. The surgeon should take the extra time to clear the anterior abdominal wall. If the adhesions are simply too

Table 6
Laparoscopy for acute diverticulitis: summary of the literature.

Authors, year	Study design	Number of Patients	Population	Outcomes
Chouillard, et al 2007[81]	Prospective database of patients who underwent laparoscopic Hartmann's procedure	31	2003-2005 Hinchey III/IV	Median op time = 125 min Median LOS = 12 d 19% conversion to open 3% mortality 6% reoperation 90% reversal
Agaba, et al 2009[82]	Retrospective review of patients who underwent laparoscopic Hartmann's procedure	7	2004-2006 Hinchey III/IV	Mean OR time = 154 min Mean LOS = 6 d 100% reversal
Fine, et al 2001[83]	Retrospective review of patients who required emergent or urgent surgical intervention for acute diverticulitis	16	1995-2000 Hinchey I – 10 Hinchey II – 6 Hinchey III - 1	Mean LOS = 7.2 d 17% conversion to open 0% mortality 6% reoperation
Titu, et al 2009[84]	Retrospective review of prospective database of laparoscopic procedures for complicated diverticular disease	66	2001-2007 Hinchey I – 27 Hinchey II – 29 Hinchey III – 7 Bleeding - 3	Median op time = 110 min Median LOS = 5 d 2% conversion to open 3% mortality 7.5% return to OR

LOS, length of stay; OR, operating room; op, operative.

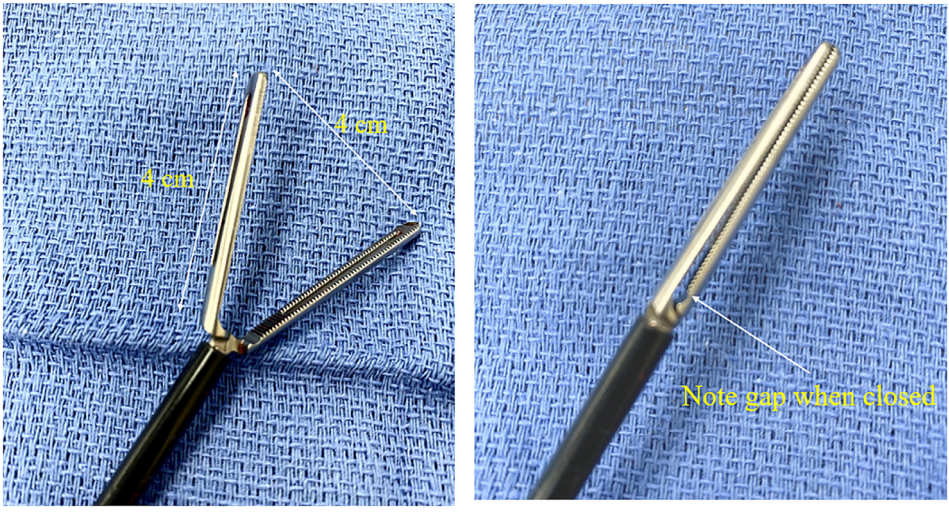


Fig. 5. Ideal bowel grasping instrument. Color version of figure is available online

dense and plentiful such that continuing dissection to allow for placement of other ports only creates injury, an open exploration should be performed.

When grasping the bowel, it is important not to pinch or partially grasp distended bowel if at all possible. The authors recommend a particular laparoscopic instrument head which is 4 cm long, opens to 4 cm, and leaves a gap when completely closed (Fig 5). It is also important to grasp the bowel at a right angle to help avoid injury. It is important to utilize retraction and as many ports as needed to provide adequate visualization. Typically, at least 4 ports will be needed: 2 working, 1 retracting, and 1 for the camera.

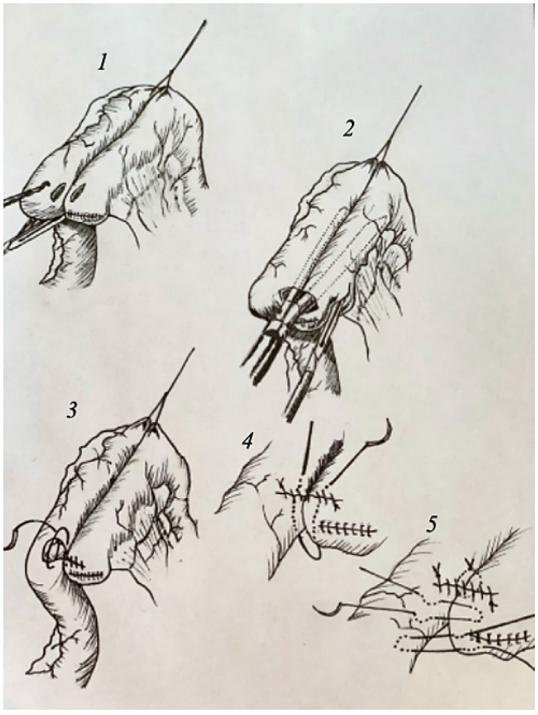


Fig. 6. Technical steps in small bowel anastomosis. 1) Line up the ends of the small bowel with a stay suture and create the enterotomies. 2) Use 60 mm linear stapler with staple heights ranging from 3.0-4.0 mm to create the anastomosis. 3) Close the common enterotomy with 2-0 absorbable suture. 4) U-stitch of 2-0 silk to buttress the staple line. 5) Two anti-obstruction sutures of 2-0 silk..

Table 7
Technical steps in laparoscopic small bowel resection.

1. Resection of the ischemic bowel.
2. Remove the ischemic bowel using a specimen retrieval pouch (ie, Endocatch^{T}).
3. Line up the proximal and distal ends of the bowel using a stay suture.
4. Create enterotomies using surgical energy.
5. Place a 60 mm linear stapler through the enterotomies and fire to create a side-to-side anastomosis.
6. Close the common enterotomy with suture, buttress with a U-stitch, and place anti-obstruction stitches.
7. Close the mesenteric defect.
8. Run the small bowel again.

After freeing up the anterior abdominal wall, the small bowel should be run from the terminal ileum proximally. It is not necessary to divide every adhesion between loops of bowel, especially if they are not currently obstructing or compromising the small bowel. After the obstruction or adhesion has been relieved, the small bowel should be run again in its entirety to ensure there were no injuries created during the exploration. Bowel with questionable perfusion can be bathed with warm saline and monitored for a few minutes after the restriction/adhesion has been removed to see if perfusion will return. If a resection is required, there are many options available for creating the anastomosis. The authors most frequently utilize a laparoscopic linear stapler anastomosis with an intracorporeally sutured closure of the common enterotomy. The resection and anastomosis can both be conducted intracorporeally (Fig 6, Table 7).

Resection of the ischemic bowel. The surgeon should divide the proximal and distal ends with a linear laparoscopic stapler. Typically, a 45 mm or 60 mm length should suffice, with a medium

height staple, of 3.0-4.0 mm. The associated mesentery should also be resected. An advanced bipolar device is recommended, taking care not to compromise the vascular supply to the remaining small bowel.

Removal of ischemic bowel. The compromised bowel should be placed in a bag prior to removal. The bag's removal can be accomplished at the end of the case, after the final checks for bleeding and other injuries are completed. The port site will likely need to be widened in order to facilitate removal, which may compromise the pneumoperitoneum.

Line up the ends of the bowel. A stay suture can help line up the bowel for the anastomosis as well as be used for retraction.

Create enterotomies. With the bowel lined up next to each other, enterotomies are made on the anti-mesenteric border on the parts of the bowel that are abutting each other. When creating the enterotomy, the assistant may hold the stay suture to create some tension and the surgeon can pull the end of the bowel in the opposite direction to create more tension. This will make creating the enterotomy easier.

Firing the stapler to create the anastomosis. We recommend a 60 mm stapler with a medium height load (3.0-4.0 mm) utilizing all of the stapler length to create the common channel.

Close the enterotomy. Using a running silk suture, close the defect. We recommend adding a U-stitch to buttress the staple line and 2 anti-obstruction stitches.

Close the mesenteric defect. We recommend permanent suture in running fashion here also.

A final run of the small bowel should be performed to look for any other enterotomies or serosal tears. Smaller ones can be treated with a single stitch or Lembert stitch. Finding the enterotomies can be difficult, so the authors recommend fixing them immediately at the time of identification or marking them with a stitch if there are multiple enterotomies that may ultimately result in a resection.

Postoperative management is similar for any bowel obstruction procedure. The authors only leave a nasogastric tube in place if the proximal bowel was significantly dilated or if there was suspected compromise. A resection does not necessarily necessitate a nasogastric tube and a clear liquid diet can be started within 24 hours.

The real benefits of the laparoscopic approach for this disease are shorter hospital stays, less nonsurgical complications (eg, respiratory, cardiac), and decreased wound infections. Although initially the laparoscopic approach may take longer, the benefit to the patient is most dramatic in the postoperative course. Consequently, it is worthwhile to persist laparoscopically if the surgeon is making progress. In cases of bowel ischemia requiring resection via a mini-laparotomy, it can be beneficial to complete the lysis of adhesions laparoscopically. This can allow for confirmation that the ischemic bowel is an isolated segment and result in a much smaller open incision (5-8 cm) that can then be used for the bowel resection and anastomosis. This hybrid technique is likely to help with postoperative pain and wound complications due to the very small size of the incision.

MIS in large bowel obstruction (Including inflammatory bowel disease)

Regardless of the etiology, large bowel obstruction typically manifests with abdominal pain and bloating associated with absence of bowel movements and flatus.[55] Large bowel obstruction is most commonly due to malignancy, while benign large bowel obstructions can be due to colonic volvulus (cecal or sigmoid) or inflammatory stricture (diverticulitis or inflammatory bowel disease).[56] Colon cancer accounts for more than one half of large bowel obstructions, and 10%-20% are due to volvulus and another 10% due to diverticular strictures.[56] In patients who are clinically stable and where colonoscopy is available, the WSES 2017 Guidelines recommend that direct visualization (and biopsy) of the site of obstruction be performed when possible (with the notable exception of cecal volvulus). Clinicians should also remember that colonic obstructions that occur in the face of a functional ileocecal valve can create a closed loop obstruction and significant dilation. As such, endoscopic means of decompression play a larger role in the initial therapy in most cases.

Table 8
Studies involving emergent laparoscopic colorectal surgery (LCS) and inflammatory bowel disease.

Comparative study	Institution	Number of patients	Main outcome
Nash et al[1]	Single	36	No difference in morbidity; Longer operating time in LCS; Shorter hospital stay
Stulberg et al[2]	Single-center	42	Less blood loss, shorter stay, less morbidity
Marceau et al[3]	Single-center	40	Similar operating time; Hospital stay similar; Morbidity similar
Fowkes et al[4]	Single-center	22	Shorter hospital stay; Similar morbidity
Seshadri et al[5]	Single-center	37	Longer operating time in LCS; No differences in complications; Less post-op morbidity; Shorter hospital stay
Watanabe et al[6]	Single-center	30	Longer operating time in LCS; Fewer post-op complications in LCS; Faster gut recovery in LCS
Qazi et al[7]	Single-center	17	Increased complications in LCS; Conversion rate of 32%
Marcello et al[8]	Single-center	16	Early oral intake in LCS; No difference in morbidity
Single cohort	**Institution**	**Number of patients**	**Main outcome**
Ouaïssi et al[9]	Single-center	18	Safe; feasible; Morbidity 33%
Bell and Seymour[10]	Single-center	18	High morbidity; Shorter hospital stay

Adapted from: Chand M, Siddiqui MR, Gupta A, *et al.* Systematic review of emergent laparoscopic colorectal surgery for benign and malignant disease. World J Gastroenterol. 2014;20(45):16956-16963.

[1] Nash GM, Bleier J, Milsom JW, Trencheva K, Sonoda T, Lee SW. Minimally invasive surgery is safe and effective for urgent and emergent colectomy. Colorectal Dis. 2010;12:480–484.

[2] Stulberg JJ, Champagne BJ, Fan Z, Horan M, Obias V, Marderstein E, Reynolds H, Delaney CP. Emergency laparoscopic colectomy: does it measure up to open? Am J Surg. 2009;197:296–301.

[3] Marceau C, Alves A, Ouaissi M, Bouhnik Y, Valleur P, Panis Y. Laparoscopic subtotal colectomy for acute or severe colitis complicating inflammatory bowel disease: a case-matched study in 88 patients. Surgery. 2007;141:640–644.

[4] Fowkes L, Krishna K, Menon A, Greenslade GL, Dixon AR. Laparoscopic emergency and elective surgery for ulcerative colitis. Colorectal Dis. 2008;10:373–378.

[5] Seshadri PA, Poulin EC, Schlachta CM, Cadeddu MO, Mamazza J. Does a laparoscopic approach to total abdominal colectomy and proctocolectomy offer advantages? Surg Endosc. 2001;15:837–842.

[6] Watanabe K, Funayama Y, Fukushima K, Shibata C, Takahashi K, Sasaki I. Hand-assisted laparoscopic vs. open subtotal colectomy for severe ulcerative colitis. Dis Colon Rectum. 2009;52:640–645.

[7] Qazi SM, Skovdal J, Munck LK, Bisgaard T. High morbidity after laparoscopic emergency colectomy for inflammatory bowel disease. Dan Med Bull. 2011;58:A4326.

[8] Marcello PW, Milsom JW, Wong SK, Brady K, Goormastic M, Fazio VW. Laparoscopic total colectomy for acute colitis: a case-control study. Dis Colon Rectum. 2001;44:1441–1445.

[9] Ouaïssi M, Alves A, Bouhnik Y, Valleur P, Panis Y. Three-step ileal pouch-anal anastomosis under total laparoscopic approach for acute or severe colitis complicating inflammatory bowel disease. J Am Coll Surg. 2006;202:637–642.

[10] Bell RL, Seymour NE. Laparoscopic treatment of fulminant ulcerative colitis. Surg Endosc. 2002;16:1778–1782.

Benign etiology

Sigmoid volvulus. In patients with a sigmoid volvulus, endoscopy is an important aspect of disease management and is generally the first line of management in the absence of peritonitis.[57,58] Nonoperative detorsion with flexible sigmoidoscopy is successful in 55%-95% of patients.[57,58] Placement of a decompression tube after successful detorsion is often used to decrease the risk of re-torsion and assist with colonic decompression and mechanical bowel preparation.[57,58]

After successful endoscopic reduction of a sigmoid volvulus, sigmoid resection with colorectal anastomosis is the management of choice in patients who are appropriate surgical candidates.[58] This resection can be performed via a mini-laparotomy or laparoscopically. The laparoscopic approach has been described in several cohort studies and is likely safe.[59–61] However, due to the redundancy of the sigmoid colon, our experience has been that it is challenging to get appropriate traction on the colon within the confines of the insufflated peritoneal cavity and thus we typically perform our sigmoidectomy and anastomosis and anastomosis via a Pfannensteil incision.

For patients who are at prohibitively high risk for surgical intervention, options for advanced endoscopic management are available, but these are not first line therapy due to a high risk of complications.[57,58] These options include percutaneous endoscopic colostomy and percutaneous endoscopic sigmoidopexy, both of which aim to create points of fixation between the colon and anterior abdominal wall to reduce mobility to prevent a recurrent volvulus. Complications from these procedures include infection, tube migration, perforation, obstruction, abdominal wall bleeding, and death.[57,58]

Cecal volvulus. Endoscopic detorsion is not recommended as first-line therapy for cecal volvulus due to the lower success rate and higher risk of perforation.[57,58] First-line interventions include resection and either primary anastomosis or ileostomy (with or without a mucous fistula). Although laparoscopic cecopexy for management of cecal volvulus has been described in the literature, the minimally invasive surgical approach is less often utilized due to the challenges presented by dilatation of the closed loop and proximal small bowel in the emergency setting.[62–64] A right hemicolectomy is recommended for both the open and laparoscopic approaches.

Inflammatory benign stricture—diverticular and inflammatory bowel disease. Strictures due to benign disease can be due to diverticular disease, inflammatory bowel disease, anastomotic strictures, and other etiologies. Colonic strictures can commonly be diagnosed and evaluated in the elective setting, but there remains a small percentage of patients with these diagnoses who present with acute on chronic obstruction.

Endoscopic stent placement for benign strictures is less commonly used due to a higher incidence of migration, perforation, and other complications when compared to malignant obstructions. Yet it has been described in the literature and best practice is yet to be defined. In a cohort of 23 patients who had successful stent placement, obstruction was relieved in 22 patients (96%) and 42% were able to avoid ostomy creation.[65] The majority of complications (87%) occurred after 7 days, and the authors recommended that surgical intervention be planned within that timeframe.

Colonic strictures in the setting of chronic ulcerative colitis are most commonly benign, although up to 25% may be due to underlying malignancy.[66] In the setting of a high rate of malignancy, and even with negative biopsies, patients with ulcerative colitis and a colonic stricture should undergo an oncologic resection. Although in the elective setting this is typically a total proctocolectomy, in the emergency setting a subtotal colectomy and end ileostomy is recommended by the American Society of Colon and Rectal Surgeons (ASCRS).

Due to the transmural inflammation in Crohn's disease, luminal narrowing of the colon with associated obstructive symptoms can occur in up to 17% of patients.[67] These strictures have an underlying malignancy in 7% of cases and differentiating between benign and malignant obstruction can be difficult. Resection should be considered if obstructive symptoms are not managed medically or if the stricture cannot be adequately assessed to exclude an underlying carcinoma.[67] Although stenting has been described in the setting of a high-risk surgical patient,[68] strictures due to inflammatory bowel disease are more commonly managed with operative intervention. The ability to use laparoscopic techniques will depend on the severity of obstruction.

Malignant etiology

Malignant stricture. Malignant strictures are often suspected based on patient history, CT imaging demonstrating metastatic disease, or appearance on colonoscopy, and when possible should be confirmed by endoscopic biopsy. CT of the abdomen and pelvis is recommended by the WSES for staging patients who present emergently and are clinically stable.[55]

Curable cancer. In patients with a proximal colonic obstruction, right hemicolectomy is the most common management strategy, and can be performed with a primary anastomosis, primary anastomosis with diverting ileostomy, or end ileostomy. Right hemicolectomy with primary anastomosis in this setting carries a leak rate ranging from 2% to 17% in the published literature.[69] If patients are identified as being at high risk for a leak, one can consider an end or diverting ileostomy.[69] Recently, the use of endoscopic stenting in obstructing right-sided colon cancers has been described.[70,71] This remains an area of conflicting recommendations. The recent ASCRS Clinical Practice Guidelines (CPG) recommend either initial colectomy or endoscopic stent decompression with interval colectomy (Grade 1C)[72] whereas in the WSES guidelines it is not recommended unless the patient is high-risk or in the palliative setting (Grade 2B and 3B).[55]

Management options for distal colonic obstruction due to curable cancer similarly include colectomy or initial endoscopic stent decompression.[72] The benefit of an endoscopically placed stent is the potential to decompress the proximal colon which can decrease the morbidity of an emergency colectomy and the need for an ostomy, while increasing the ability to perform MIS. In a meta-analysis, stent placement was associated with a 7% risk of colon perforation during placement.[73] Recent ASCRS CPGs recommend either colectomy or stent with interval colectomy for obstructing left-sided colon cancer (Grade 1B).[72] In the case of rectal cancer, endoscopic biopsy and stenting should be performed, when possible, to decompress the large intestine and allow for neoadjuvant therapy. In either colon or rectal cancer cases, the main goal of endoscopic therapy is to convert an urgent case to an elective or time-sensitive one.

For elective cases, the minimally invasive approach for colectomy for colon cancer is recommended by the ASCRS CPG (Grade 1A).[72] No recommendations are provided for laparoscopic versus open approach to proximal or distal colonic obstructions. When colectomy is used as the initial treatment option for obstructing colon masses, a minimally invasive technique can be challenging due to the significant amount of upstream dilatation,[55] although it is possible and has demonstrated increased operative time with no difference in complication rates in small studies.[74] Patients who are able to be decompressed safely with endoscopic stenting are more likely to be managed successfully with minimally invasive techniques and this is one of the reasons we typically pursue this as our first line management.[74] Even with locally advanced cancers that require an open approach for safe dissection, our experience has been that, if the proximal colon can be decompressed, we can at a minimum still mobilize the splenic flexure laparoscopically and minimize the size of the incision required.

Unresectable or incurable cancer. In patients with large bowel obstruction who are more appropriate for palliative management than curative intent, management options include colectomy, proximal diversion, and endoscopic stenting. Endoscopic stenting is the recommended management due to decreased interval to initiation of chemotherapy.[72] Endoscopic stenting also avoids surgical morbidity and mortality without decreasing survival.[72] For patients in whom stenting is not possible and who are unfit for general anesthesia, loop colostomy remains an option.[55]

In general it may be more difficult to manage large bowel obstructions with a MIS technique due to the dilation of the colon and because of the high concern for malignancy. However, with the exception of the cecal volvulus, endoscopy should initially be used to decompress, which in addition to allowing time for resuscitation of the patient, may enable the use of laparoscopic techniques with the same benefit to the patients that laparoscopy provides.

MIS in large bowel inflammation (Including inflammatory bowel disease)

Large bowel inflammation can be related to many etiologies including infectious (diverticulitis, *Clostridium difficile*), ischemic, or inflammatory bowel disease. Sequelae of inflammation of the colon can result in a stricture with upstream obstruction, adjacent abscess, perforation, hemorrhage, and non-resolving symptoms. Determination of the etiology will be based upon clinical history, imaging (typically CT), and laboratory values. CT with intravenous (IV) contrast can be

particularly useful in differentiating inflammation from ischemia from that associated with infection or inflammatory bowel disease (IBD). *C. difficile* infection is commonly characterized by diffuse inflammation and is diagnosed by stool antigen testing and less commonly colonoscopy to assess for pseudomembranes. Determination of whether the patient has diverticulitis or IBD can be challenging in cases in which there is a high level of suspicion for both, although diverticulitis is much more common. Occasionally, endoscopic evaluation may assist in the diagnosis.

Diverticulitis

The acute inflammation present in diverticulitis can create additional challenges to the laparoscopic colon resection due to distortion of anatomical planes. Multiple studies have reported a successful laparoscopic approach for acute diverticulitis (Table 6), generally showing improved outcomes, although there is significant bias in the selection of patients and publication of data. The ASCRS 2020 Guidelines for the management of left-sided colonic diverticulitis recommend that, when expertise is available, the minimally invasive approach, including both laparoscopy and a robot-assisted approach, is safe. The recommendation includes that the surgeon must assess the safety of this approach after considering the patient's hemodynamic stability, bowel dilation, previous abdominal surgery, and the presence of comorbidities.[75]

Laparoscopic lavage emerged in the last decade as an alternative to anatomic resection, with mixed outcomes. In a recent multicenter prospective observational study, laparoscopic peritoneal lavage was associated with increased incidence of reoperation, ongoing sepsis, and higher recurrence rates.[76] Additionally, laparoscopic lavage is only advocated for Hinchey III diverticulitis, which ultimately may not be determined until there is direct visualization of the abdomen. The 2020 ASCRS Guidelines for the management of left-sided colonic diverticulitis recommends colectomy for both feculent and purulent peritonitis.[75]

Clostridium difficile

The laparoscopic approach for *C. difficile* was not addressed in the 2014 systematic review[74] and we were unable to find any literature reporting attempts at laparoscopic total colectomy in the setting of fulminant *C. difficile* infection. Typically, when these patients require surgical intervention, they are critically ill, with dilated colon, and the open approach is safest.

In 2011, surgeons at the University of Pittsburgh reported their results with management of *C. difficile* via laparoscopic loop ileostomy creation and colonic lavage.[77] Successful completion of laparoscopic diversion was achieved in 83% of patients, whereas the remainder were converted to laparotomy.[77] Although this approach generated significant enthusiasm as an alternative for total abdominal colectomy, mortality rates remain high with either approach. In a recent 2020 meta-analysis, mortality rates were not significantly different between total abdominal colectomy and loop ileostomy, although there remained limitations due to the observational nature of the studies and risk of selection bias.[78]

Inflammatory bowel disease

The primary management of acute inflammation in patients with IBD is focused on medical management. When this fails in the setting of toxic colitis, non-resolving inflammation, or perforation, surgical intervention may be required. In a 2014 systematic review, 10 studies (8 comparative) were identified, with a total of 286 cases in which patients underwent open or laparoscopic surgery for management of ulcerative colitis or Crohn's disease of the colon (Table 8).[74] The authors described a general trend of shorter hospital stay, increased operative times, and equivalent or slightly better outcomes in the laparoscopic approach compared to the open approach.

Inflammation due to ischemia

Colonic ischemia can also manifest as colonic inflammation and may be in the differential with the other etiologies discussed here. Patient history and CT with IV contrast are often valuable, and endoscopic evaluation of mucosal perfusion can also provide additional information. Management of acute colonic ischemia can range from supportive care to anatomic resection,

depending on the etiology and severity. Indications for surgical intervention include peritonitis, hemodynamic instability, isolated right colon ischemia, and pancolonic ischemia or colonic gangrene.[79] When surgical intervention is needed, the laparoscopic approach may be technically feasible, depending on the amount of inflammation and potential for perforation, but often the patient's physiology limits the practicality of pneumoperitoneum and the increased operative time often associated with laparoscopic approach. Thus, not surprisingly, a 2013 single site review of surgical management for acute ischemic colitis does not mention the laparoscopic approach.[80]

For inflammation of the large bowel, there are no definitive data that recommend laparoscopy over the open approach. The laparoscopic washout for Hinchey III diverticulitis may have a role for the patient with significant comorbidities that needs control of the infection, but this approach is more likely to require a reoperation. The damage control approach to *C. difficile* colitis and the laparoscopic approach to ischemic events of the colon does not seem to improve outcomes over an open resection, likely owing to the high risk of the disease. The use of MIS techniques in patients with IBD, however, seems to show benefits seen with other laparoscopically treated diseases.

MIS in bariatric emergencies

Bariatric procedures for weight loss and metabolic disease are primarily performed by the growing number of fellowship-trained bariatric surgeons. Sometimes patients travel to other cities to have their operation. The common bariatric complications can occur at any time over the lifetime of the patients. As such, it is not unusual for patients to present acutely to an emergency room where a bariatric surgeon is not available.[85] Minimally invasive techniques can be very useful in managing these complications.

Initial evaluation

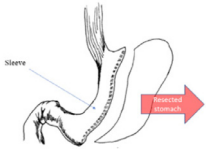
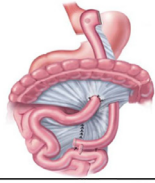
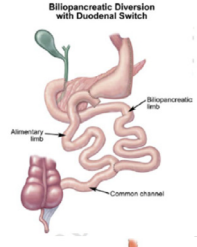
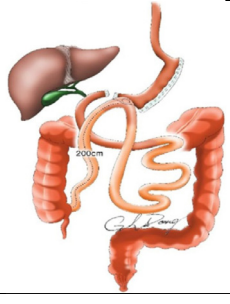
Bariatric patients will commonly present with abdominal pain or oral intolerance, which have a broad differential diagnosis in this population. In evaluating a bariatric patient, it is important to remember that the first few months after a procedure are a time of great physiologic change. Although the patient is expected to experience a lot of physiologic improvements, they may also be malnourished, chronically dehydrated, and immunosuppressed. It is also important to know exactly what procedure they have had, yet it is common for the patient to either not know or misstate the specific procedure. This is especially true if the patient had a less commonly performed one, such as one-anastomosis gastric bypass (OAGB), duodenal switch (DS), or single-anastomosis duodenal ileal bypass (SADI), or a historical procedure such as vertical banded gastroplasty (VBG). As such, it is imperative that surgeons have a working knowledge each of these different procedures (Table 9).

The main reasons for emergency or urgent reoperations or interventions on post-bariatric surgery patients are leaks, SBOs, marginal ulcers, gallstone complications, and band complications. There are also several situations that the astute clinician should look for in bariatric patients: portal vein thrombosis, suicide attempts, alcoholism, and acute thiamine deficiency.

Initial management

Regardless of the cause of the presenting symptoms, bariatric patients will often need IV fluid resuscitation and admission. These patients are chronically dehydrated and are unable to replenish fluids quickly via the oral route due to their surgically altered anatomy. Patients may have significant symptom improvement with only IV hydration, but clinicians should have a low threshold for admitting these patients to allow for a proper evaluation. Upon admission, surgeons should test for malnutrition and make sure that patients receive appropriate nutrition supplementation while waiting for test results to return.

Table 9
Types of bariatric procedures.

Type	Illustration	Mechanism of weight loss	Features
Sleeve gastrectomy (SG)[1]		Restrictive Hormonal	80% of the stomach is removed
Roux-en-Y gastric bypass (RYGB)[2]		Restrictive Hormonal Malabsorptive	30 cc pouch 2 anastomoses 75-150 cm Roux limb 50-125 cm biliopancreatic limb
One anastomosis gastric bypass (OAGB) a/k/a mini-gastric bypass[3]		Restrictive Hormonal Malabsorptive	45-60 cc pouch 1 anastomosis 150-200 cm afferent limb
Duodenal switch (DS)[2]		Restrictive Hormonal Malabsorptive	Sleeve Gastrectomy and distal bypass 2 anastomoses Alimentary tract limb anastomosed to the 1st portion of the duodenum Long biliopancreatic limb 100-150cm common channel
Single anastomosis duodenal-ileal bypass (SADI)[4]		Restrictive Hormonal Malabsorptive	Sleeve gastrectomy 1 anastomosis Efferent limb 250-300 cm

[1] SG original illustration by Robert Lim, MD
[2] RYGB Credit to Cine-Med publishing, 2007 and DS Cine-Med publishing, 2010
[3] OAGB Credit to O'Brien, P Surgical Treatment of Obesity Endotext [Internet]. Feingold KR, Anawalt B, Boyce A, et al., editors. South Dartmouth (MA): MDText.com, Inc.; 2000.
[4] 4SADI https://www.sciencedirect.com/science/article/abs/pii/S155072891830501X

Leaks

Anastomotic leaks are the most dreaded complication of bariatric procedures. They can substantially increase the mortality and morbidity for bariatric patients. Most leaks occur after discharge from the hospital. Patients most commonly present with abdominal pain, fevers, dyspnea, and even a feeling of doom. Approximately 70% of patients who present with tachycardia and

Table 10
Bariatric procedures, intragastric pressure, and leaks.

Low pressure leaks	High pressure leaks*
Roux-en-Y gastric bypass (RYGB) One-anastomosis gastric bypass (OAGB) or mini-gastric bypass	Sleeve gastrectomy (GS) Duodenal switch (DS) Single anastomosis duodenal-ileal bypass (SADI)

* These procedures have 2 sphincters involved, the lower esophageal and pyloric, that cause higher pressures within the sleeve portion of the procedure that makes leaks difficult to close.

Table 11
Important considerations in managing a leak after bariatric surgery.

1. Hemodynamically unstable patients need an operation to wash out the infectious material and to control the source of the inflammation.
2. Patients with sustained tachycardia need an operation even if radiologic studies do not show a leak.
3. Low pressure leaks (RYGB, OAGB) are likely to close with an intervention.
4. High pressure leaks (sleeve gastrectomy, DS, SADI) need an intervention to close the leak as well as a procedure to relieve distal obstruction.
5. Select patients who are hemodynamically normal or who appear well clinically can be managed with radiology directed drainage, antibiotics, either distal enteral feeding or parenteral nutrition, and a therapeutic endoscopic intervention.

RYGB, Roux-en-Y gastric bypass; OAGB, one-anastomosis gastric bypass; DS, duodenal switch; SADI, single anastomosis duodenal-ileal bypass.

Table 12
Tenets of leak repair after bariatric surgery.

1.Irrigation of the abdomen. There is no required minimum amount, but it should be generous (at least 2 L) in order to wash out all the areas where fluid can flow.
2.Repair or buttress the leak. If the leak can be found and the tissue is reasonable, a primary repair or classic Graham patch should be performed. If primary repair is performed, the authors recommend interrupted sutures so that if one suture breaks or pulls through, the rest of the repair is more likely to stay intact. If the leak cannot be found, endoscopy should be considered to help locate the disruption. If the leak still cannot be found, then one should proceed with drainage.
3.Widely drain the surgical area. Place drains near the area of concern and in areas where fluid is likely to flow.
4.Ensure feeding access. This may consist of a gastric tube in the remnant stomach of a RYGB or a feeding tube in one of the limbs of the bypass (Roux, biliopancreatic, or common channel).

RYGB, Roux-en-Y gastric bypass.

dyspnea have an anastomotic leak.[86] Either an abdominal CT with oral contrast or an upper GI series can be performed to identify a leak. These studies do not require more than 300 cc of oral contrast to provide useful information and the contrast can be consumed immediately before the study is performed. These studies, though, are only 50%-94% sensitive for finding a leak.[87] Therefore, a negative study does not necessarily mean a leak is not present. Similarly, an abscess or a fluid collection near a staple line is a leak until proven otherwise. There are a few important concepts to remember when managing a leak (Table 10, Table 11).

Once the diagnosis of a leak is made (either radiographically or clinically) and a decision is made for operative intervention, the approach can be laparoscopic. Attention should be focused on the stapled bowel and anastomoses which are the most common sites of leaks. Although most leaks occur in the foregut, surgeons should not forget to examine the distal anastomosis of a Roux-en-Y gastric bypass (RYGB) or DS. If no anastomotic leaks are identified, the remainder of the hollow viscus organs should be examined as there can be injury during retraction. If there is a substantial amount of inflammatory fluid, this will cause peritonitis, resulting in the abdominal wall musculature to contract, even under adequate general anesthesia. Surgeons may find that visualization is poor upon initial entry. Suctioning out the inflammatory fluid, pus, and enteric contents will help the abdominal wall to relax, allowing better visualization. The tenets of the procedure are summarized in Table 12.

Once the leak has been repaired or stabilized, a leak test should be performed postoperatively before starting oral intake, typically around the first or second postoperative day or when

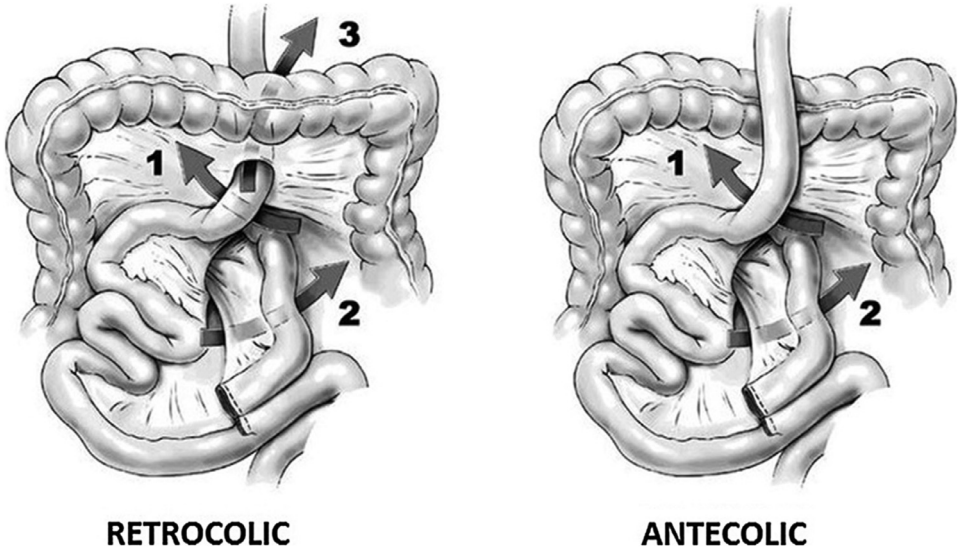


Fig. 7. Possible internal hernia sites. Credit to both the Journal of the Society of Laparoscopic Surgeons and the Society of Laparoscopic & Robotic Surgeons (SLS). Color version of figure is available online.

the patient is more stable. The authors recommend an upper GI series for this situation because the patient can be maneuvered to show more views of a potential leak. If the leak is repaired, then oral feeding can be started. If a small leak is noted that is controlled by the drains, then this patient likely needs more time to heal and only distal feeding should be implemented. If a large leak persists and no other cause for the drainage is present, then therapeutic endoscopy with clipping, suturing, or vacuum sponge should be considered. This portion of management of a large leak will likely take some time (perhaps weeks to months) and repeated endoscopic attempts before the leak will close. If there is a large cavity adjacent to the site of the leak, endoscopically enlarging the connection to allow for better drainage of the contents back into the stomach may be beneficial.[88,89] During this time, provided the patient remains hemodynamically stable, the best thing to do is avoid another operation as additional injuries may occur.

Regarding leak management, there is one more important tenet. High pressure leaks require that the distal "obstruction" is addressed. Sleeve gastrectomy, DS, and SADI operations have high-pressure areas because there are 2 sphincters (gastroesophageal and pyloric) at each end of the sleeve anatomy (Table 10). Any additional pressure on the staple lines caused by a gastric sleeve that is too narrow or has a twist, stenosis, or kink will cause a leak and subsequently make the leak less likely to close. Consequently, these "obstructions" need to be corrected before a leak will close or a repair will hold. Most of these can be addressed with the help of therapeutic endoscopy. A stenosis, kink, or narrowing of the gastric sleeve can be treated by balloon dilation and/or stent placement. They may require serial dilations or stent placement for up to 6 weeks. In the case of a twist, however, this is unlikely to be corrected by endoscopic measures. In this case, and in cases in which the "obstruction" cannot be corrected endoscopically, a reoperation to perform a RYGB or even an esophago-jejunal bypass is indicated.

Bowel obstructions

SBOs have been described as the Achilles heel of RYGBs and occur in approximately 5% of patients who undergo this procedure.[90] Like all SBOs, they can be caused by adhesive disease, ventral wall hernias (especially at port sites larger than 10 mm), and, with bypass anatomy, via an internal hernia (Fig 7). Patients will present with symptoms of a bowel obstruction and the diagnostic procedure of choice is an abdominal CT with IV and oral contrast.[91] A mesenteric

swirl sign is highly suspicious for an internal hernia and other signs include 2 transition points and loops of bowel in the left upper quadrant (LUQ). As in patients with a leak, a CT without the above findings does not rule out an internal hernia or bowel obstruction. A dilated remnant stomach indicates the biliopancreatic limb is obstructed. If there is oral contrast present in the gastric remnant, then the obstruction is distal to the jeju-jejunostomy anastomosis. The only other way contrast can get to the remnant is if there is a fistula between the gastric pouch and the gastric remnant.

In patients with signs of perforation, ischemia, or hemodynamic instability, exploration should be undertaken and again, it can typically be accomplished laparoscopically. Entry can be achieved using any of the described methods, but surgeons should review the CT and try to avoid any entry in the areas where dilated loops are likely to be found. If the abdominal cavity is entirely filled with dilated small bowel, then the open Hassan technique again is likely the safest approach. Again, several ports should be used for proper exposure. The decompressed distal bowel should be examined first and run proximally to help find the area where the obstruction is occurring and to avoid over-manipulating distended bowel which may create an enterotomy. Although beginning examination of the small bowel at the terminal ileum and working proximally is always useful in SBO cases, it is particularly useful in patients with bariatric anatomy as this is the region most likely to be surgically unaltered and is valuable for orientation.

The most common site of an internal hernia is the jeju-jejunostomy mesenteric defect. Internal hernias can also occur behind the Roux limb as it passes in front of the transverse colon (antecolic) or behind the Roux limb as it passes through the transverse mesocolon (retrocolic), also known as the Peterson defect. If a retrocolic Roux limb has been constructed, then the bowel can herniate through the transverse mesocolon defect itself. If on the CT, most of the small bowel is in the LUQ, then likely the patient has a transverse mesocolic defect. In the case of the DS, the SADI, or the OAGB, the internal hernia can occur around any of the sites where the bowel passes behind limbs that connect to the duodenum. In all of these situations, being familiar with the proper anatomy is paramount.

The authors recommend labeling the limbs of a RYGB using metallic clips to help identify the anatomy: 1 clip on the Roux limb, 2 clips on the biliopancreatic limb, and 3 clips on the common channel. The likely internal hernia sites should be explored and if a hernia is found, it should be reduced. If the obstruction cannot be relieved laparoscopically, this is an indication for conversion to open operation. After the hernia has been reduced or relieved, the internal hernia defect should be closed.

Marginal ulcers

Marginal ulcers can manifest with pain, melena, or decreased or complete oral intolerance. They should be suspected in bariatric patients who use tobacco products or who regularly take nonsteroidal anti-inflammatory medications. They can occur in any of the bariatric procedures that have an anastomosis but can be more problematic in patients who have had the RYGB and the OAGB, as ulcer disease can be present in the excluded portion of stomach as well. Most ulcers can be treated with a 6-week course of a proton pump inhibitor, alone or in combination with sucralfate and misoprostal.[92] These patients should also be tested for an active *H. pylori* infection and evaluated for a gastro-gastric fistula, whereby the acid content of the remnant stomach can enter the gastric pouch, increasing the chance of developing an ulcer.

Similar to PUD, these patients can also present with perforation or bleeding. In patients who present with perforation, an omental patch repair will suffice. Intraoperative endoscopy can help identify the perforation. The authors advocate for a laparoscopic approach due to the benefits of laparoscopy. Surgeons should be prepared for succus and inflammatory fluid just as with an anastomotic leak. Management of the perforated ulcer should include omental patch repair, washout, drain placement, and consideration for distal enteral feeding tube access.

In marginal ulcers that manifest with bleeding, endoscopic and interventional radiology treatment options should be explored first. Again, gastroenterologists and acute care surgeons should be facile with endoscopic techniques to control bleeding, including clip placement, epinephrine

injection, and suturing. Endoscopic evaluation should include identification of foreign bodies, such as a staple or suture, that may be contributing to the ulcer formation and can be removed endoscopically. If the bleeding cannot be controlled radiologically or endoscopically, then surgical management is necessary, which may include a revision of the gastrojejunostomy and removal of the previous anastomosis. This may be approached laparoscopically when the surgeon has that skill set. Revision of the gastrojejunal anastomosis may be uncomfortable for some surgeons, and in this case an open approach is advised. When revising the anastomosis, the surgeon should try to preserve the gastric pedicle and be careful not to devascularize the pouch, which will lead to a leak. Usually there is plenty of Roux limb, so sacrificing a few centimeters will not result in malnutrition or weight regain.

Chronic marginal ulcers or ones that do not respond to medical therapy and subsequently lead to stenosis and oral intolerance typically do not require acute management. These should be referred to a bariatric surgeon for a revision.

Gastric prolapse and band erosion

Although adjustable gastric bands are not placed nearly as frequently as they were in the early 2000s, there are still patients with adjustable bands in place. One may even encounter some of the older non-adjustable gastric bands. These bands will not be connected to a port. The reoperation rate for bands is approximately 20%-40%, and the most common reasons for emergency band removal are gastric incarceration/strangulation after a gastric prolapse or band erosion.[93] A gastric prolapse can be suspected if the position of the gastric band is not 45° from the spine on an anterior-posterior (AP) radiograph. Patients with prolapse, severe abdominal pain, and oral intolerance can be suspected of having an incarcerated stomach, therefore requiring emergency removal of the band.

Upon laparoscopic exploration, the surgeon can use the band's tubing to help locate the band. The band can be divided with scissors or with the use of monopolar energy. There will often be scar tissue around the band which can make removal more difficult. This scar tissue can also be safety dissected with surgical energy. Bands are often imbricated with stomach to help hold them in place during initial placement. This imbrication should be divided to help relieve the incarceration and this can be accomplished with a stapler (Fig 8). Finally, there is often a band of scar tissue around the stomach which can result in restriction even after the band has been removed. This scar only needs to be fenestrated to relieve the restriction. It will be very difficult to remove the entire scar and attempts to do so will likely lead to more injury. Fenestration is safe and should allow the prolapsed or incarcerated stomach to reduce. If there is evidence of necrotic or ischemic tissue, it can be resected as a wedge with a stapler.

Choledocholithiasis

Rapid weight loss from bariatric surgery is associated with the formation of gallstones, but only approximately 10% of patients who have undergone a bariatric procedure will develop symptoms and need to undergo a cholecystectomy.[94] Patients with CBD stones will have the same presentation as in those who have had not bariatric surgery, but because of the previous gastric surgery, the management may be different. For sleeve gastrectomy patients, there is no difference in management because the duodenum is still accessible by standard endoscopy and thus ERCP can be performed when appropriate.

For patients who have undergone a RYGB, the CBD is accessible by double-balloon endoscopy going down the Roux limb and back up the biliopancreatic limb to access the ampulla of Vater. However, many endoscopists do not do this routinely. The common bile duct is also accessible via percutaneous transhepatic cholangiography (PTHC), but this requires the biliary ducts to be dilated for the radiologist to access them. The laparoscopic assisted trans-gastric approach is a well-described option. In this approach, the surgeon provides access to the remnant stomach for the endoscopist. To do so, the author recommends suturing the remnant stomach to the anterior abdominal wall, then making a gastrotomy. A laparoscopic port can then be placed into the gastrotomy. To facilitate an ERCP scope, the port must be 15 mm in size. Laparoscopic ports with a balloon are often used to help keep the port in place. ERCP can then be completed and,

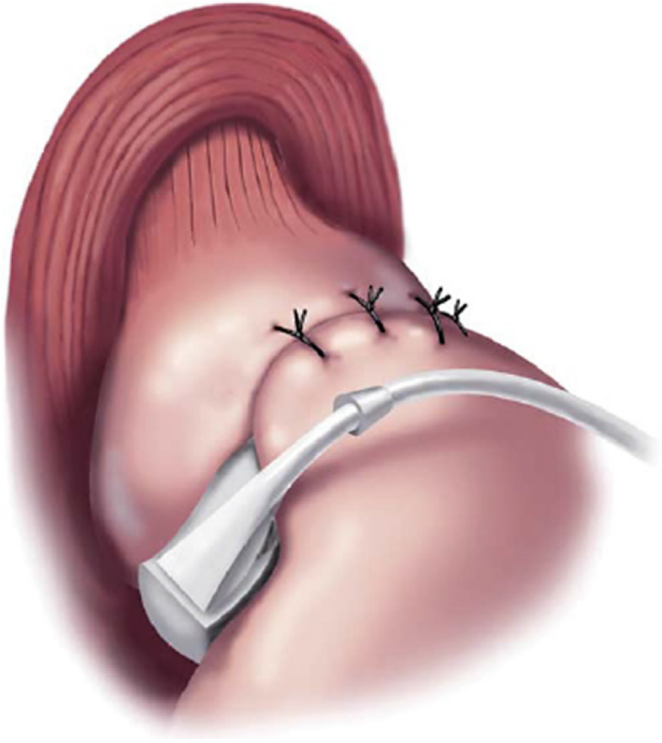


Fig. 8. Gastric band imbrication: stomach is sutured to itself around the band to help keep it from slipping [Cine-Med, publishing, 2007]. Color version of figure is available online.

after the duct is cleared, the port is removed, the stay suture is removed, and the gastrotomy can be closed with a stapler or suture.

Some endoscopists are able to do a trans-gastric ERCP by connecting the gastric pouch to the gastric remnant using US guidance. By creating a fistula, the endoscopist is then able to perform a standard ERCP. This is not commonly available, but it is an option in some places.[95] If the trans-gastric ERCP cannot be accomplished, then a LCBDE can be performed. In patients with choledocholithiasis who present with pancreatitis, that entity can be initially treated just as one would in a patient without bariatric anatomy, and if the choledocholithiasis persists undergo management as above. However, trans-gastric drainage of a pancreatic pseudocyst may require some of the advanced techniques described here.

Summary

There are certainly many etiologies in the differential diagnosis of abdominal pain in the post-bariatric surgery patient. Appendicitis, renal stones, ectopic pregnancies, urinary tract infections, and others are not affected by the bariatric anatomy and these should be considered when consulting on post-bariatric patients. The diseases described in this section are the ones that require emergency intervention such that the clinician may not have the opportunity to transfer the patient back to the bariatric surgeon. As such, it is paramount that acute care surgeons are able to recognize and understand the anatomy of the different bariatric procedures. Understanding the internal anatomy is one reason why the standard initial radiologic evaluation of a bariatric patient demands a CT with oral contrast. Surgeons should not hesitate to repeat a scan if oral contrast is not used initially. Immediate exploration should be performed in patients with hemodynamic instability or with a persistent, yet undiagnosed, reason for tachycardia. With

the information above, the acute care surgeon should be able to diagnose and treat the majority of these events with minimally invasive techniques. For their part, bariatric surgeons should be readily willing to accept those patients who can safely be transferred, even if they are not the original operating surgeon.

MIS in mesenteric ischemia

There is an emerging role for the use of laparoscopy in the management of intestinal ischemia. This has been proposed since the early 1990s when laparoscopy began being used more commonly.[96] Just as with other acute surgical diseases, there is a role for use of minimally invasive techniques that provides benefit to the patient. Yet regular use in this patient population is rarely seen.

Diagnostic role

CT angiography is very sensitive for diagnosing acute mesenteric ischemia, but many patients with concern for acute mesenteric ischemia may also have acute renal failure, known renal failure, or contrast allergies which prevents them from having a contrast study. Additionally, some patients may still have a high clinical suspicion for acute mesenteric ischemia despite imaging without evidence of ischemia. In a 2013 retrospective study, 53 patients with a negative CT angiogram underwent laparoscopic exploration, with 42 (77.1%) having mesenteric ischemia. This study highlights that a negative CT angiogram does not always rule out mesenteric ischemia, and also that 20% of patients avoided an unnecessary laparotomy. There was no reported mortality related to the diagnostic laparoscopy.[40]

Mesenteric ischemia is a known but uncommon complication of aortic dissection, cardiac surgery, and aortic aneurysm repair. As many of these aortic diseases are treated with endovascular techniques, the bowel is often not directly visualized.[97] A diagnostic laparoscopy can be utilized to determine if there is ischemic intestine in these patients, who are often critically ill; and although the data are not of the highest-quality, it is a safe approach.[98–101]

Non-occlusive mesenteric ischemia (NOMI) is an entity that typically occurs in critically ill patients due to another disease such as septic shock or a recent myocardial infarction. The suspicion of NOMI in critically ill patients represents a diagnostic dilemma; failure to respond to treatment for the underlying disease could be due to the underlying disease or to the sequelae of NOMI itself. At the same time, surgical exploration may be unnecessary and place the already critically ill patient at even higher risk of morbidity and mortality. Bedside 3-port laparoscopy has been studied retrospectively in this population. In the patients with a finding of ischemia on laparoscopic exploration, the authors employed a “second look” protocol at 48 hours, resulting in further resection 66% of the time. The mortality rate was much higher in the resected group, at approximately 45% vs 11% in the group that did not undergo resection. Forty-five percent of patients in this study avoided a non-therapeutic laparotomy.[98] In cases of pneumatosis intestinalis, the use of laparoscopy has been described as a safe way to evaluate the bowel and determine if resection is needed.[102]

Early recognition of mesenteric ischemia is key to limiting morbidity and mortality from this life-threatening condition. Conversely, ischemia can develop over time and early surgical evaluation may not always identify frank necrosis or nonviable bowel. A “second look” at 24-48 hours is therefore advocated with the laparoscopic approach.[103,104]

Adjuncts and tips

With the laparoscopic approach, there is loss of the tactile sensation of a cold, flaccid bowel, which can sometimes be useful in determining if bowel is ischemic or frankly necrotic. Additionally, a palpable pulse cannot be detected with laparoscopy. There are laparoscopic Doppler devices available, but these may not be readily available after hours when these cases often occur. Laparoscopic exploration can be augmented by immunofluorescence. ICG has been described as a safe way to evaluate ischemic bowel.[99,105] This requires near infra-red light which

will show uptake of the ICG dye wherever blood flows[106]. Although this may change some operative decision-making, there is no evidence that this improves mortality or even successful anastomoses.

Bedside laparoscopy

Bedside laparoscopy in the intensive care unit has been described and it appears that it can avoid a non-diagnostic laparotomy in up to 46% of critically ill patients depending on the suspected etiology of the intra-abdominal concern.[107] The described methods include a 3-port approach, with 1 camera port and 2 working ports.[107] However, an adequate exploration for an injury often requires 5 - 6 ports to provide better retraction. A 3-port exploration may result in an inadequate exploration and ultimately a missed area of ischemia. Conversely, surgeons should have a lower threshold for proceeding with a laparotomy if there is a questionable area of intestine or if a full exploration cannot be accomplished. We also described the use of gravity to provide an exploration, which may not be possible on an ICU bed. The surgeon should try to take advantage of what movement the ICU bed allows, though, as it can help with the exploration. Finally, this will require an ICU room with a lot of space to accommodate the laparoscopy tower, the sterile table, as well as any of the equipment the patient already requires due to their critical illness, such as a mechanical ventilator. Although it may be technically possible to resect the non-viable bowel laparoscopically, this will require additional equipment. Generally, any procedure that goes beyond a laparoscopic exploration should probably be moved to the OR where that equipment is readily available. The available data all describe conversion to an open procedure when ischemia is found, most likely because these patients are critically ill or hemodynamically unstable and thus speed is of the essence.

Combined endovascular procedures

The use of endovascular procedures to treat acute superior mesenteric artery thrombosis or occlusion does allow for visualization of the intestines. As such, vascular surgeons may request evaluation of the intestines and this can be accomplished using laparoscopy. Endovascular suites are typically located in the OR area, but they utilize a bed that is not ideal for laparoscopic surgery. Patients are placed on a fluoroscopy bed that slides and raises but does not incline or tilt. This makes a laparoscopic exploration more challenging; and even open approaches can be difficult on these beds. The authors recommend that after the endovascular procedure is completed, the patient should be transferred to a standard OR table to allow for an optimal operation.

Summary

Laparoscopy is a useful adjunct in the management of suspected mesenteric ischemia. It can help avoid a non-diagnostic laparotomy in 20%-45% of patients in whom the diagnosis is uncertain. It can also readily identify patients who have mesenteric ischemia despite a negative radiologic and laboratory evaluation. It does not appear to increase morbidity or mortality; however, the available data are retrospective studies with small numbers of patients, so whether or not this impacts survival is not known. Additionally, there is likely bias in that the patients who have had a negative laparoscopic exploration are patients who may be less sick than others and thus have an inherent survival advantage. Whether or not an open exploration would have increased their likelihood of demise is not known.

MIS in incarcerated hernias

Patients with incarcerated hernias repeatedly demonstrate worse outcomes compared to their elective counterparts.[108–110] Despite this well-documented fact, incarcerated hernias will continue to occur for patients who do not have affordable access to elective surgical care, who have been evaluated and determined to be too high risk for elective surgical intervention, or ones who do not present until an incarceration has occurred. One option to improve outcomes for

patients with incarcerated hernias is to utilize a MIS approach, which is generally safe when feasible. The ability to do so remains dependent on the patient, the extent of the disease, the surgeon's comfort, and, in the case of the robot-assisted laparoscopic approach, the hospital's characteristics.

Ventral hernia

Minimally invasive approaches, both laparoscopic and robotic-assisted, are feasible for many incarcerated ventral hernias. There remains no definitive consensus regarding the best approach for incarcerated ventral and incisional hernias.[110] In addition to the usual factors influencing the approach, such as surgeon expertise, local hospital resources, and patient habitus, specific hernia characteristics and upstream bowel dilation will also contribute to the decision making. For elective ventral hernia repairs, the only randomized controlled trial comparing surgical approaches that we could identify found that the laparoscopic technique was associated with lower rates of short-term postoperative complications, 50% decreased odds of overall complications at 8 weeks, and decreased pain at 1-year follow-up. At the same time, the laparoscopic cohort had higher rates of more severe complications, particularly bowel injury, although this was not statistically significant.[111]

In 2017, the WSES outlined guidelines for emergency repair of complicated abdominal wall hernias. They recommended that the laparoscopic repair of incarcerated hernias may be performed in cases without bowel strangulation or the need for bowel resection (Grade 2C).[112] During laparoscopy, traction is created between the bowel and the abdominal wall with the assistance of the pneumoperitoneum, allowing for visualization of planes for dissection and identification of occult hernias.[113,114] In open cases, similar traction between the bowel and abdominal wall is achieved with manual retraction and can be physically demanding. Three case series have reported on experience with the laparoscopic approach to incarcerated hernias and concluded that it is feasible and safe (Table 13).[115–117] Even in cases of bowel strangulation, we find the laparoscopic approach useful, as it is sometimes possible to resolve the strangulation by reduction of the hernia contents which allows for rapid reperfusion and ongoing assessment. When bowel resection is needed, the laparoscopic approach still allows for a mini laparotomy to be performed at a location chosen based on both intra-abdominal and extra-abdominal findings. A randomized controlled trial is unlikely to be practical for patients with incarcerated hernia, and ultimately the decision to pursue an open or laparoscopic approach will be at the discretion of the operating surgeon. Surgeons who are comfortable with laparoscopy should feel confident that the safety of this approach in the incarcerated hernia is supported by current literature. Technical guidelines for laparoscopy in the reoperative abdomen are reviewed in the "Previous Abdominal Surgery" chapter of the SAGES manual on Basic Laparoscopy and Endoscopy.[118]

Inguinal hernia

Incarcerated inguinal hernias can similarly be approached in a myriad of ways. Although the concepts outlined above are generally applicable to incarcerated inguinal hernias, additional literature regarding this specific clinical scenario is available. The WSES 2017 Guideline recommendations are unaltered with regard to inguinal and femoral hernias.[112] A systematic review in 2009 concluded that a laparoscopic approach to the incarcerated or strangulated inguinal hernia was safe, with a 2% rate of conversion to open operation and a 5% rate of requiring a bowel resection.[119] The placement of mesh in the preperitoneal space makes permanent synthetic mesh placement safe in laparoscopic repairs, except in the rare case of gross contamination of the preperitoneal space. In the case of femoral hernias, these more often require a bowel resection, perhaps due to the fact that they typically occur in elderly women.[120] As such, the laparoscopic approach, as opposed to the inguinal approach, allows for visualization of the small bowel to determine if resection is needed. Alternatively, an open inguinal approach can be used for repair and a diagnostic laparoscopy can be performed to evaluate for ischemia of the incarcerated contents.

Table 13
Reports of laparoscopic repair of incarcerated ventral hernias.

Study	N	Repair	Hernia content	OR	LOS	Complications	Exclusion criteria
Olmi (2009)	48	All laparoscopic, with new-gen composite meshes (Parietex)	66% bowel, 34% omentum	Mean OR time 62 min; 4% rate of enterotomies	Mean 4 d (range 3-6 d)	0% mesh infection, 0% hernia recurrence, 16% seroma rate (median f/u 38 months)	Need for bowel resection, loss of domain
Shah (2008)	112	103 laparoscopic, 7 primary repair and 2 converted to open	62% bowel, 38% omentum	Mean OR time 96 min; 4% rate of enterotomies	Mean 2.8 d (range 1-6.5 d)	20.5% complication rate, 1% mesh infection, 3% hernia recurrence, 14% seroma rate (mean f/u 48 mo)	Gross abdominal distention due to massively inflated bowel, peritonitis, general condition that contraindicated laparoscopy
Landau (2004)	25	All laparoscopic with Gore-Tex Dual Mesh (ePTFE)	84% bowel, 72% with omentum	Mean OR time 63 min; 4% rate of enterotomies, 4% bleeding	Median LOS 3.2 d (range 2 - 7 d)	0% mesh infection, 0% hernia recurrence, 12% seroma rate (median f/u 23 mo)	<4 prior laparotomies, <10cm hernia, surgeon's judgement, conversion to open due to bowel necrosis

OR, operating room; LOS, length of stay; PTFE, polytetrafluoroethylene.

Parastomal hernia

Parastomal hernias are one of the more complex hernias that manifest as surgical emergencies. Many of the concepts previously reviewed regarding ventral hernia are applicable to parastomal hernias as well. In the United States, 20% of parastomal hernia repairs are performed during an emergency admission.[121] Parastomal hernia repairs are associated with a significantly increased risk of postoperative complications compared to ventral hernias and emergency repair is an independent risk factor for increased postoperative complications.[121–123] Full reduction of a parastomal hernia may be more challenging than a routine ventral hernia due to the presence of the ostomy. In the elective setting, the best option for parastomal hernia repair is to restore intestinal continuity when possible,[124] but is often not feasible in the non-elective setting. Further discussion of surgical techniques can be found in the recent review published by Shah and colleagues.[125] Technical pearls reviewed include patient positioning, placement of a Foley balloon catheter in the ostomy, and tips for orienting the mesh.

In general, incarcerated hernias are another disease for which laparoscopy may be beneficial. The outcomes do not appear to be any worse with an MIS approach; and again, the patients may be benefit from decreased surgical stress.

MIS in trauma

The use of laparoscopy in trauma situations is becoming more prevalent for both penetrating and blunt injuries.[126–128] One of the main benefits is that it prevents the need for a laparotomy, as it can be used for both diagnostic and therapeutic purposes. The main tenets of the laparoscopic approach are that patients must be hemodynamically stable and a thorough and systematic exploration must be performed with the proper equipment and with proper maneuvers.

Laparoscopic candidates

It is not possible to place too much emphasis on the importance of hemodynamic stability when using the laparoscopic approach. Trauma patients who are not hemodynamically stable should not undergo a laparoscopic approach. The laparoscopic approach can be considered in stable patients with penetrating abdominal trauma to first determine if there is peritoneal violation. In thin patients, this may be a simple enough task via bedside exploration; but in obese patients, adequate bedside assessment may require an incision that is several centimeters long. Even then, the clinician may not be able to determine if the peritoneum is violated, especially if there is a large amount of preperitoneal fat.

For the trauma patient, the initial evaluation remains unchanged; a thorough primary and secondary survey is required. For patients with abdominal and pelvic penetrating injuries or a positive focused assessment with sonography for trauma (FAST) scan, the next most appropriate step is abdominal CT to evaluate for organ injury. However, a CT is not necessarily reliable in determining peritoneal violation, specifically bowel injuries. A retrospective review of 274 patients evaluated with single-contrast CT showed a penetrating injury sensitivity of 88%, specificity of 72%, positive predictive value of 82%, and negative predictive value of 80% for detecting bowel injuries.[129] A meta-analysis published in 2011 showed that although CT using triple contrast had high specificity and sensitivity, at approximately 94%-95%, its positive predictive value for the need for laparotomy was lower, at 84%.[130] Thus, there is still a significant missed injury rate and a false positive rate when using CT evaluation for penetrating injuries.

Laparoscopy, though, has proven to be a good adjunct in the evaluation of penetrating injuries. There are 4 situations in which laparoscopy has a role: (1) the patient with a concerning physical examination but an equivocal or negative CT; (2) the patient with a normal physical examination but with free fluid on CT; (3) the patient whose physical examination or whose complaints worsen during a period of observation despite remaining hemodynamically stable; and (4) the patient with a left chest or left upper abdomen penetrating injury and no other injuries, in which a diaphragm injury cannot be ruled out.

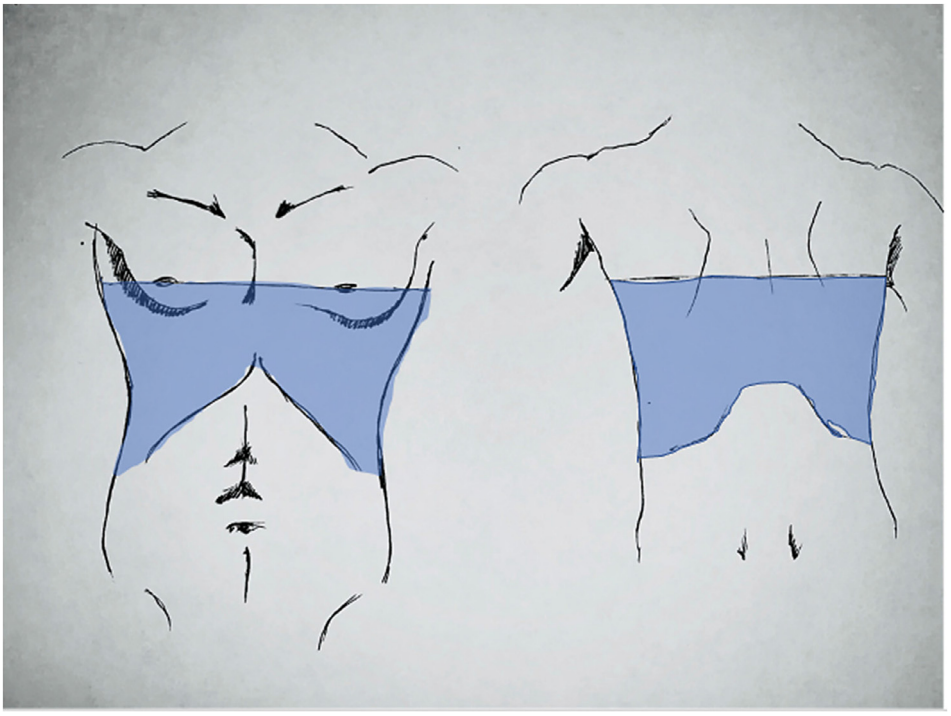


Fig. 9. Thoracoabdominal box: wounds to this portion of the chest should also be concerning for injuries to the abdomen, including the diaphragm..

These patients can undergo a laparoscopic exploration and, if the exploration is negative, patients can avoid a laparotomy incision. This has resulted in shorter hospital stays, fewer wound infections, and a lower postoperative ileus rate without an increase in missed injuries.[127] For those patients, this approach has almost eliminated the negative laparotomy rate.[131]

Special mention should be made about the use of laparoscopy in patients with penetrating wounds to the left chest and left upper abdomen in whom a diaphragm injury is possible (Fig 9). For patients with these injuries who remain hemodynamically stable, an occult diaphragm injury is difficult to diagnose, as CT and US are notoriously unreliable for this injury. For such injuries, a laparoscopic exploration is recommended in a semi-elective fashion to rule out a diaphragm injury.[132] With this approach, an occult injury can be found 20%-30% of the time.[132,133]

Laparoscopic exploration

As stated before, an important tenet of the laparoscopic approach is to perform a thorough and systematic exploration. This would include the ability to run the entire bowel, evaluate the retroperitoneum, examine the lesser sac, and view the pelvis. To do so, the surgeon should have at least 2 working ports. Including a camera port then, the literature recommends that a proper exploration requires at least 3 ports.[134,135] The authors, however, recommend that at least 4 ports be used so that an assistant can help retract. The patient should be prepared so that he or she can be safely placed in positions that help with retraction and visualization.

The pneumoperitoneum can be established through any of the described techniques. Often the site of the penetrating injury to the abdominal wall can be used to place a port. After establishing a pneumoperitoneum, ports should be placed in both the right and left sides at approximately the level of the umbilicus. This will typically allow reach to both the pelvis and the foregut.

Table 14
Technical steps in laparoscopic exploration for trauma.

1. Examine the right hemidiaphragm, liver, and gallbladder.
2. Examine the left hemidiaphragm, spleen, and anterior stomach.
3. Divide gastrocolic ligament to examine the posterior stomach, retrogastric area, pancreas, and duodenum.
4. Reduce the amount of reverse Trendelenburg position to approximately 10° and elevate the transverse mesocolon. Identify the ligament of Treitz to run the small bowel to the terminal ileum.

Hints:
- Place the bowel in the upper quadrants while running it to deliver the distal small bowel and cecum cephalad.
- Place the camera in one of the lower ports to help visualize the distal small bowel more easily.
- Pay attention to the mesentery as well as the bowel.
- Be sure to look for violations into the root of the mesentery for zone I injuries

Lower Abdominal Exploration (patient in Trendelenburg position)

1. Run the small bowel a second time from the terminal ileum to the ligament of Treitz.

Hints:
- Place the bowel in the pelvis when running to help deliver the proximal jejunum caudad.
- Place the camera in one of the more cephalad ports to help visualize the proximal small bowel easier.

2. Examine the right colon. Place patient in a right-sided up position. If a right zone II injury is suspected, division of the white line of Toldt along the ascending colon should be performed to visualize the retroperitoneum there.
3. Examine the transverse colon. Patient should be placed in a reverse Trendelenburg position to keep the small bowel in the pelvis.
4. Examine the left colon. Patient should be re-placed in the Trendelenburg position and the left side should be elevated. Again, if a left zone II injury is suspected, the white line of Toldt should be divided to mobilize the colon.
5. Examine the sigmoid colon, rectum, and pelvis. Allow small bowel to fall in a cephalad direction and remember to look for zone III injuries

After the ports are placed, the first step would be the same as if an open technique were used: control bleeding or contamination, if present. Next, a systematic approach to search for other injuries should be conducted. The initial control of bleeding or perforation can be accomplished with clamps, staplers, clips, surgical energy, or sutures. It is important to reinforce that the goal is to gain control of the injury. If attempts to do so result in more injuries, if the bleeding becomes uncontrollable laparoscopically, or if the patient becomes hemodynamically unstable, then the wise decision would be to convert to an open procedure rather than persist laparoscopically.

After initial control of any identified injuries is obtained, or if no obvious injuries are found, a systematic exploration should be undertaken. The author prefers examining the upper abdomen first, then the lower abdomen.[135] To do so, the patient is placed in steep reverse Trendelenburg position which allows the small bowel to drop into the pelvis and out of view. Once the gastrocolic ligament is divided, the transverse colon will also fall in the caudad direction allowing better visualization of the posterior stomach, pancreas, and duodenum.

Upper abdomen exploration can proceed with the patient in reverse Trendelenburg position (Table 14). Further routine exploration of the retroperitoneum is not required if there is no suspicion of a retroperitoneal injury, such as an expanding hematoma or a concerning injury seen on CT. With the use of laparoscopy, a non-therapeutic laparotomy can be avoided approximately 60% of the time.[135]

Therapeutic laparoscopy

The decision to repair injuries via a laparoscopic technique ultimately depends on the surgeon's skill and comfort with performing these procedures. However, acute care surgeons should be able to repair small enterotomies laparoscopically, repair diaphragm injuries, resect and anastomose injured bowel, or resect small parts of injured solid organs. At the same time, a thorough laparoscopic exploration can often allow for a more limited laparotomy, if needed, which would likely also reduce the patient's postoperative morbidity.

Summary

Laparoscopy is most useful in a subset of patients in the trauma population—patients who do not have devastating injuries requiring emergent repair and patients who do not have substantial injuries that would be easily seen on CT. In trauma patients who are hemodynamically stable, especially those with small but potentially devastating injuries, laparoscopy becomes a valuable adjunct for both diagnosis and therapy. Laparoscopy has been described to close traumatic hollow viscus perforations, to resect and anastomose intestines, control bleeding from solid organs or from mesenteric vessels, perform splenectomy, repair bladder injuries, repair diaphragm injuries, drain pancreatic injuries, perform cholecystectomies, and repair liver lacerations. Whereas these patients would historically undergo a laparotomy, within the last 10-15 years there has been a growing number of surgeons who use laparoscopy in these situations. This approach has all the benefits of laparoscopy seen in other disciplines of surgery, such as decreased pain and decreased wound complications. A formal and systematic exploration can be performed with the use of at least 4 ports, however the surgeon should not hesitate to add more ports to aid with retraction and exposure.

MIS in enteric tube placement and dislodgement

Enteric tube placement can be performed to improve nutrition (in the setting of dysphagia or other inability to tolerate oral intake) or to provide longer-term decompression (in the setting of benign or malignant obstruction).[136,137] Substantial detail on patient assessment, preoperative evaluation, and postoperative management of patients with gastrostomy tubes are provided in the book, "Percutaneous Endoscopic Gastrostomy [PEG]: Techniques, effectiveness, and potential complications" by Eric Pauli and Jeffrey Marks.[137] Here, we review the broad range of minimally invasive techniques for gastrostomy and jejunostomy tube placement and defer to that excellent reference for details on the nuances of PEG placement.

Gastrostomy

Minimally invasive placement of a gastrostomy tube can be achieved via many approaches, including PEG (in an endoscopy suite or the OR), percutaneous gastrostomy placement by an interventional radiologist, laparoscopic-assisted PEG, and laparoscopic gastrostomy creation. PEG placement can be accomplished via a "pull" or "push" (also referred to as introducer) technique, both of which include performing an upper endoscopy, identifying an ideal site for the tube placement, and creating a single incision through which to pass the gastrostomy tube. Identification of a site for PEG placement can include transillumination, one-to-one palpation, and the "safe-tract" method.[138] Although the techniques when performed in the OR and the endoscopy suite are the same, we find it easier to place patients in reverse Trendelenburg position in the OR with the use of a footboard, which can sometimes provide the gravitational pull needed to identify a place where the stomach directly apposes the abdominal wall.

Laparoscopic assistance can be provided in cases in which apposition of the stomach and abdominal wall is not confidently identified with endoscopic assistance.[139] This can range from laparoscopic-assisted PEG to laparoscopic gastrostomy tube placement. In the laparoscopic-assisted PEG, one to two 5 mm ports are inserted and a camera, sometimes with the assistance of a grasper, is used to visualize the intraabdominal portions of PEG placement and confirm that there are no organs between the stomach and the anterior abdominal wall. In these scenarios, abdominal insufflation should be kept to a minimum (8-12 mmHg depending on patient habitus) to allow the stomach to be pulled to the abdominal wall without undue tension.

In cases in which the stomach is under significant tension, there is an inability to insufflate the stomach, or patients are thought to be at high risk for tube dislodgement, laparoscopic gastrostomy tube placement is a viable alternative for safe minimally invasive gastrostomy tube placement. There are a variety of techniques for this option, and our group typically utilizes a single purse string suture around the site of gastrostomy tube placement and 4 Stamm-style sutures placed in a diamond shape around the gastrostomy tube insertion site.

Percutaneous gastrostomy tubes placed by the radiologist are referred to by many names, including percutaneous radiologic gastrostomy (PRG), flouoroscopy-guided gastrostomy, and radiologically inserted gastrostomy.[140] Standard placement was described almost 30 years ago.[141] Using the radiographic approach for gastrostomy tube placement has the advantage of not requiring sedation and may have some additional benefit in the setting of significant esophageal stenosis or malignant oropharyngeal obstruction.

Early gastrostomy tube displacement occurs in 2%-28% of cases.[142] When this occurs early (1-2 weeks), the tract may not yet have had time to fully mature and there is risk of leakage of gastric contents and resultant peritonitis and sepsis. Management options in this scenario range from conservative management with nasogastric tube decompression and antibiotics to laparotomy, depending on the patient's clinical picture.[143] When patients have signs of sepsis, they should undergo emergent operative intervention with closure of the previous gastrostomy. Clinically stable patients can undergo laparoscopic gastrostomy placement (typically with Stamm suture and potentially drainage, if needed). Endoscopic management options are less often used but are well described elsewhere[137]; and thus, if advanced endoscopy is available, laparotomy or laparoscopy may not be required.

Jejunostomy

Endoscopic jejunostomy placement can be performed in a manner similar to the PEG techniques described above in cases in which there is a functional intestine and a contraindication to gastrostomy tube placement. This technique is excellently described by Boules and colleagues.[144] Although this approach has a higher failure rate (32%),[145] when successful it can offer a durable option for post-pyloric enteral access.[146] Complications include bowel perforation, volvulus, bleeding, and aspiration.[145]

Laparoscopic jejunostomy placement is probably the most commonly utilized approach for minimally invasive jejunostomy tube placement and was described as early as 1999.[147] There are a variety of techniques available depending on surgical skill, experience, local resources, and preferences. Critical components include apposition of the jejunum to the anterior abdominal wall, accurately identifying the proximal and distal limbs to ensure the that the jejunostomy tube is inserted in the efferent limb, and pexying the jejunum to avoid volvulus. Instructional videos are also available online (Laparoscopic Jejunostomy, SAGES).[148] It is often valuable to place metallic clips on the sutures approximating the bowel to the abdominal wall to help localize the site if future percutaneous placement is desired.

Early jejunostomy tube dislodgement is possible, but much less common than with gastrostomy tubes. Because of the reliance on sutures (rather than balloons) to appose the bowel to the abdominal wall, dislodgement is less likely to result in leakage and sepsis and can often be managed nonoperatively.

MIS in acute care patients

The other equally important aspect of acute care surgery is the underlying physiologic status of the acute care patients. The previously discussed acute care diseases alone are enough to bring about a devastating physiologic derangement, but their underlying medical diseases make acute care patients the most complex and challenging patients for providers and hospital systems. MIS techniques can sometimes worsen these derangements but oftentimes provide a better option when caring for these difficult patients.

MIS in cardiac disease

Abdominal insufflation, or pneumoperitoneum, impacts the cardiovascular system via both increased intra-abdominal pressure and hypercarbia. Elevated intra-abdominal pressure can result in relative compression of venous flow, most notably impacting venous cardiac return via the inferior vena cava. Additionally, right atrial pressure is increased due to initial rises in

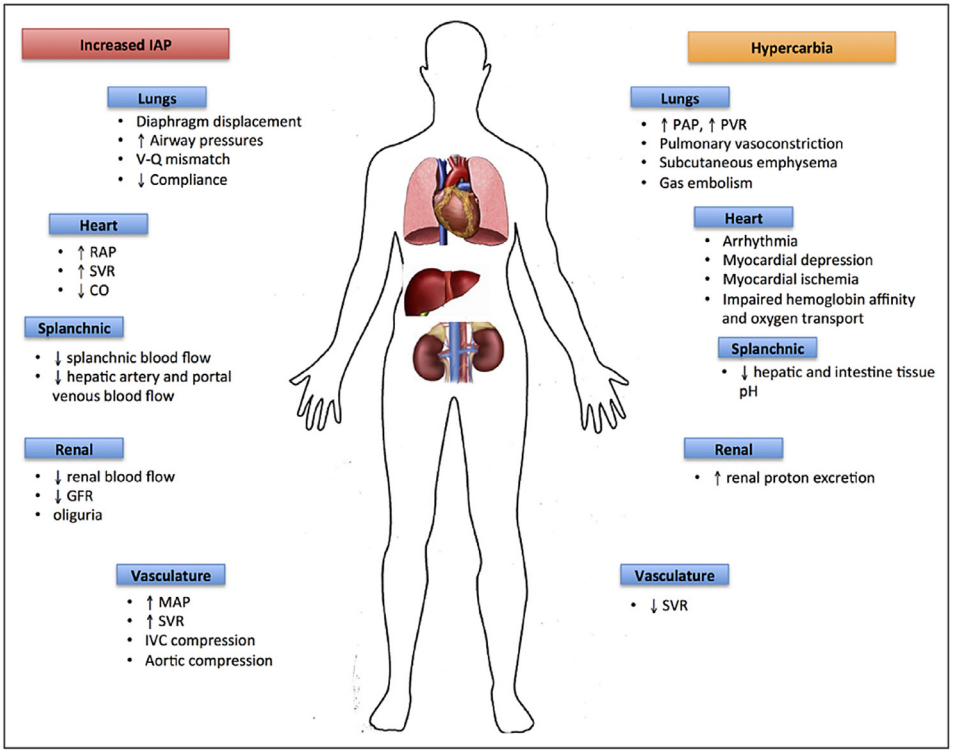


Fig. 10. Two components of laparoscopic surgery. Detrimental effects of increased IAP and hypercarbia. CO, cardiac output; GFR, glomerular filtration rate; IAP, intra-abdominal pressure; MAP, mean arterial pressure; PAP, pulmonary artery pressure; RAP, right atrial pressure; SVR, systemic vascular resistance. Color version of figure is available online.

inferior vena cava pressures and later decreased splanchnic blood flow which redistributes blood volume into the central venous system.[149] The impact of pneumoperitoneum on mean arterial pressure and systemic vascular resistance is also mediated by neuroendocrine effects (Fig 10).[149] The ultimate effect on cardiovascular function is increased left ventricular preload and afterload and a decrease in cardiac function, which return to baseline 30 minutes after return to normal abdominal pressures.[149]

Aside from the technical challenges of EGS, part of the reason this specialty sees very high morbidity and mortality rates is the underlying comorbidities of the patients. Of the many diseases discussed in this monograph, heart disease is probably the most challenging and the most common one. A prospective study using echocardiography on elderly patients undergoing emergency non-cardiac surgery found that 75% of the patients had some form of cardiac disease.[150] There are not many options immediately available to mitigate the cardiac risk preoperatively in at-risk emergent patients. The occurrence of a major adverse cardiac event (MACE) can be very devastating to the patient, as the risk of death is 2.7-fold greater than in patients without one.[151] Consequently, cardiac risk evaluation must be considered in all patients undergoing EGS. The risk of the procedure is based on consideration of both the patient's underlying cardiac condition and the risk level of the procedure, and then must be weighed against the risk of any attempts at nonoperative management.

Coronary artery disease

Preoperative angina increases the risk of a postoperative cardiac event by 2.6-fold and a MACE occurs approximately 5.5% of the time.[152] By definition, none of the EGS procedures

should be considered low risk procedures (typically reserved for plastic surgery cases, cataract surgery, and the like). The risk of a MACE at the individual patient level is defined as the combined risk of the surgical procedure and the patient's comorbidities; low risk is a combined risk of MACE less than 1% and all others (>1%) would be an elevated risk. An emergency procedure is one that will result in loss of life or limb if surgery is not performed within 6 hours. An urgent one is described as one that will result in loss of life or limb if not performed within 6-24 hours. A time-sensitive procedure should be performed from 1 day and up to 6 weeks later (ie, malignancy cases that do not need any acute intervention).[153]

Elevated risk patients can be identified initially by an accurate history and physical examination. Patients with a past medical history of recent myocardial infarction (MI), known congestive heart failure (CHF), a recent echocardiogram with an ejection fraction of less than 30%, known cerebrovascular accident (CVA) within the past year, exercise tolerance of less than 6 metabolic equivalents (METS), and active angina should immediately be identified as being high risk from a cardiac perspective. A dobutamine stress test can accurately predict the risk of an actual MI,[154] however it is not feasible to obtain this test in patients in need of EGS.

In patients with a recent MI, it is recommended to wait 6 months before proceeding with a surgical procedure. Although the MACE risk actually decreases after 60 days, the stroke risk continues to be elevated for approximately 6 months post-MI and carries an 8-fold increase in perioperative mortality.[155] In scenarios in which patients can be stabilized for that length of time (such as with a cholecystostomy tube for acute cholecystitis or antibiotic management of appendicitis or diverticulitis), that may be the better option for the patient.

In patients with known heart disease, symptomatic left ventricular dysfunction carries a 49% MACE rate; and those patients with a known ejection fraction less than 30% have the highest risk of death.[156] In the absence of a reliable medical record, heart failure can be strongly suspected in those patients with paroxysmal nocturnal dyspnea, dyspnea on exertion, angina, and orthopnea. In patients who are unable to provide a reliable history, signs of pulmonary edema, bilateral rales, a third heart sound gallop, and pulmonary vasculature redistribution on chest radiograph strongly suggest CHF.

Even in patients with asymptomatic left ventricular dysfunction, there is a 23% MACE rate, which means that asymptomatic patients also carry a high risk of morbidity.[156] The following diagnoses are considered relative contraindications for elective non-cardiac surgery: acute coronary syndrome (active MI), acute decompensated heart failure, arrhythmias associated with hypotension, and severe aortic stenosis. It is not clear how much more risk this provides in patients who need emergency or urgent surgical care.

Valvular heart disease

The presence of valvular heart disease can also negatively affect surgical outcomes. Symptomatic valvular disease is marked by similar symptoms such as dyspnea and angina on exertion, syncope, and orthopnea. The evaluation of valvular disease should include an echocardiogram even in the emergency setting, when possible, to determine the type of valvular disease (stenosis or regurgitation) and the severity of associated heart dysfunction.[153] In general, stenosis carries a worse prognosis than regurgitation. In the case of aortic stenosis, a pressure gradient of more than 40 mmHg across the valve or a peak velocity more than 4 m/s across the valve are contraindications to elective surgery.[153] Patients who present with this disease in the emergency setting are thus at very high risk for a poor outcome.

Patients with known valvular heart disease should be managed with intensive perioperative monitoring (which may include transesophageal echocardiography), avoidance of hypotension and hypertension, and avoidance of anemia.

Arrhythmias

Tachycardia. Atrial fibrillation and flutter are the most commonly encountered arrhythmias seen in surgical patients, occurring up to 30% of the time.[153] The presence of these arrhythmias themselves do not increase the risk of morbidity and mortality, but they do predispose to other supraventricular tachycardias. Management can include prophylactic amiodarone which reduces

the incidence of atrial fibrillation but does not impact the overall hospital length of stay.[157] Beta-blockade is the preferred treatment, but the negative ionotropic effects may worsen CHF, if present.[153] Electrical cardioversion is reserved for patients with hemodynamic compromise. Frequent premature beats and non-sustained ventricular tachycardia is not associated with MACE in the perioperative period although they can be associated with a more permanent arrhythmia.

Bradycardia. This is usually due to medications, electrolyte disturbances, hypoxemia, pain, or ischemia.[153] Severe bradycardia can lead to heart block and will typically respond to atropine, aminophylline, and correction of the underlying abnormalities. For those patients with persistent bradyarrhythmias due to a sinus node or atrioventricular node block, pacemaking is often indicated.[153]

Congestive heart failure

Despite the concerns regarding the impact of laparoscopy on cardiac function intraoperatively, there are few data regarding postoperative outcomes in patients with CHF who undergo laparoscopic abdominal surgery. This is further complicated by the fact that CHF is typically identified broadly in large databases. In ICD-9 codes, CHF was classified as systolic versus diastolic versus combined and as acute or chronic, which lacks specificity in the severity of disease. In the American College of Surgeons National Surgical Quality Improvement Project (ACS-NSQIP) database, history of CHF is defined as being present if the patient has a new diagnosis of CHF in the 30 days prior to surgery or if the patient has chronic CHF with new signs or symptoms in the 30-day period.[158] In a retrospective study of NSQIP patients with CHF undergoing appendectomy, colectomy, small bowel resection, splenectomy, and ventral hernia repair, laparoscopy was associated with improved 30-day postoperative outcomes in multivariable analysis.[158] Not surprisingly, there was a greater percentage of patients with a recent history of CHF in the non-elective surgical subset. In this type of retrospective study, patients were preoperatively assessed and identified as appropriate for the laparoscopic approach based on variables that are likely not available in the NSQIP database, including severity of the CHF and specific ejection fraction data. Despite these limitations, this is the most comprehensive study we were able to identify that supports laparoscopy as a safe alternative approach in appropriately selected patients.

Ultimately, laparoscopy is likely safe in the patient with compensated heart failure. Patients with heart failure who cannot compensate for the changes associated with increased abdominal pressure may ultimately present with hypotension and cardiogenic shock. Consultation of a cardiovascular colleague in the setting of severe heart failure will often be prudent to help optimize the patient preoperatively and postoperatively. Techniques to do so include optimizing fluid status preoperatively, titrating medications, and managing perioperative hypertension with vasodilators.[149] Close postoperative monitoring will allow for early intervention to avoid postoperative complications.

Implantable devices

Many patients may have cardiovascular implantable electronic devices (CIED) due to arrhythmias, structural heart disease, or heart failure resulting in the need for a device to support a functional rhythm and effective cardiac output. It is important to know why the patient has the device and its settings whenever possible. A CIED that only fires when bradycardia is detected may not need to be adjusted at all since the patient's regular rhythm does not depend on it. If the CIED is set to pace the patient synchronously, it can be changed to the asynchronous setting such that it will provide a functional rhythm regardless of what rhythm the patient experiences from the acute disease or emergent surgery.

CIEDs can be deactivated by placing a magnet over the device.[159] In the case of a CIED pacemaker, the magnet will put the pacemaker into asynchronous mode automatically, which will ensure that the patient has some functional rhythm. In the case of the CIED defibrillator, the magnet will deactivate the CIED's ability to convert fibrillation, but it will still provide a pacing function. The surgical team should have a reliable and quick method to reactivate the CIED along with having external defibrillation immediately available in case ventricular tachycardia or fibrillation occurs. All patients with CIEDs in place should have reliable blood pressure monitoring

in case the CIED is interrupted or fires during the case resulting in hypotension.[153] The CIED can be reactivated simply by removing the magnet.

An important consideration regarding CIEDs is the type of electrosurgical energy that is to be used during the procedure. The use of monopolar energy may cause the CIED to fire or be interrupted, resulting in a cardiac complication. When possible, the surgeon should use bipolar energy or ultrasonic energy as these modalities do not transfer current through the patient's body to a dispersion pad. As such, they have less likelihood of causing an inadvertent stoppage or firing of the CIED. Placing the dispersion pad away from the implantable device, including the wires, will draw the current away from the CIED, which will also help prevent disruption of the device. Decreasing the amount of time the monopolar device is fired and operating inferior to the level of the umbilicus (if able) also decreases the chance of CIED malfunction.[160]

Stents

Patients with drug eluting coronary artery stents (DES) require dual antiplatelet therapy (DAPT), typically aspirin and an antiplatelet inhibitor such as clopidogrel. There is a high rate of stent thrombosis in the first 6 weeks after DES placement. If patients require an emergency surgical procedure during the first 6 weeks, the surgeon should consider continuing both therapies, if possible, and at least the aspirin if the antiplatelet inhibitor is determined to be too high risk. After 6 weeks, the American Heart Association (AHA) recommends continuing aspirin because there is an ongoing, although decreased, risk of thrombosis. Best practice has not yet been definitively identified, but after 365 days (and some would suggest 180 days), it is safe to stop all antiplatelet therapy for an emergency procedure.[153]

Estimating risk

Regardless of the type of heart disease, surgeons need to estimate the potential impact of emergency or urgent surgery for patients who present with concurrent heart disease. This information will direct perioperative management and can be of great value when counseling the patient (or family members if the patient is incapacitated). The Revised Cardiac Risk Index is a validated tool that can estimate the likelihood of a cardiac event and death in surgical patients, however it may not be as reliable in acute care surgery patients. Similarly, the data from ACS-NSQIP have produced a risk calculator that takes into account the type of surgery being performed, whether it is elective or emergent, and the frailty of the patient.[161] Both can give the surgeon, the surgical team, the patient, and the patient's family a good idea of the anticipated outcomes after surgery. For patients who present with acute symptoms of heart disease, the beta-type natriuretic peptide (BNP) level should be obtained as it can make the cardiac outcome predictions more accurate.[162]

General management

The AHA has produced guidelines on how to manage patients with heart disease perioperatively, but unfortunately very little is said about emergency situations. The vast majority of EGS patients have situations in which the risk of not operating is equal to or greater than operating; and those with heart disease have an increased risk of a MACE with both operative and nonoperative management. Estimating the risk of perioperative complications via a risk calculator can certainly inform decision making, yet ultimately surgeons who care for patients with EGS diagnoses will likely find themselves in situations in which both operating and not operating will be high risk to the patient. In general, these patients should have intraoperative and postoperative hemodynamic monitoring to include an arterial line and telemetry. The surgical team should do their best to avoid tachycardia, hypertension, hypotension, and anemia.

There was some excitement about the use of beta-blockade in the perioperative period due to the DECREASE trials published in the early 2000s. However, the more definitive meta-analyses showed that although beta-blockers did decrease the rate of MACEs, the stroke and mortality rates were increased.[153] Patients taking beta-blockers prior to surgery should continue them; and those that were not taking them at baseline should be started on them judiciously.

Overall, the use of laparoscopy does not appear to increase or decrease the risk of morbidity and mortality for emergency surgical procedures in patients with cardiac comorbidities. The authors, therefore, recommend that the global picture of the patient's physiologic status be used to help determine the approach.

Chronic obstructive pulmonary disease

Abdominal insufflation for laparoscopy has pulmonary effects in addition to cardiovascular effects. The most significant impact may be due to the cephalad displacement of the diaphragm, which can increase airway pressures.[149] There is also increased circulating partial pressure of CO_2 which can require increased ventilatory rate to maintain this within the normal range. The pulmonary complications related to these changes include hypercarbia, hypoxemia, reduced pulmonary compliance, and subcutaneous emphysema .[149] In the setting of chronic obstructive pulmonary disease (COPD), these changes can result in significant ventilation-perfusion mismatch and abnormal gas exchange.[149] The resultant acidosis can often be managed with hyperventilation, but if not, may necessitate conversion to open operation. In the setting of severe COPD, patients are at increased risk of pneumothorax from bullae rupture if higher pressures are needed for ventilation.[149] On the other hand, the benefit of decreased postoperative pain in the setting of a minimally invasive approach and the avoidance of a large upper abdominal incision may significantly improve the postoperative respiratory status.

In the acute care surgery setting, there are not short-term interventions that can significantly optimize patients with COPD for surgery. Although options exist for performing surgery under regional anesthesia,[163,164] the literature is mixed regarding outcomes for COPD patients who undergo laparoscopic cholecystectomy.[165,166] A recent meta-analysis of patients undergoing laparoscopy in GI surgery concluded that the laparoscopic approach was safe and feasible, with short-term benefits for properly selected COPD patients.[167] Unfortunately, there are not adequate data to identify criteria for when a laparoscopic approach is prohibitive in patients due to their COPD. Our general approach is to attempt the laparoscopic approach whenever otherwise feasible in the acute care surgery patient based on extrapolation from the elective surgery literature. In patients who have severe end-stage pulmonary disease, consideration for laparoscopy under regional anesthesia[168] or an open approach with generous local pain control techniques (such as a transversus abdominis plane block)[169,170] are both feasible alternatives.

Malnutriton

Minimally invasive approaches appear to show a benefit in patients who are malnourished, perhaps owing to fewer wound complications and fewer infections that are more often seen with open operations. In the elective setting, there is evidence that the laparoscopic approach is superior to the open approach for cancer patients who are malnourished, without a negative impact on long-term cancer outcomes.[171] The data for the emergency populations is sparse, however. In general, though, malnourished acute care surgery patients experience more complications regardless of the surgical approach.[172–174]

The laparoscopic approach certainly does not eliminate the risk of complications in malnourished patients. For patients who undergo a laparoscopic cholecystectomy, including emergency procedures, an albumin of less than 4.0 g/dL is associated with an increased risk of mortality, and the lower the albumin, the greater the risk.[175] For patients with an acute complication from Crohn's disease who required urgent surgical intervention, malnutrition was associated with an increased likelihood of laparoscopic failure and conversion to an open approach.[176] The patients who were successfully managed laparoscopically saw shorter lengths of hospital stay and faster return to oral intake.[176] This study suggests that there is a benefit to the patient if the procedure can be completed laparoscopically and that if a temporizing procedure could be accomplished that allows patients time to improve their nutrition status, it should be considered.

In frail patients awaiting major abdominal surgery, outcomes were improved using multimodal prehabilitation with as little as 5 days of nutritional intervention. Mortality at 30 days was decreased from 14% in patients who did not have prehabilitation to 0% in those who did. At 90 days, the difference was 28% vs 0%.[177] The European Society for Clinical Nutrition and Metabolism (ESPEN) recommends nutrition for 7-14 days in malnourished patients prior to undergoing elective surgery, even if it means delaying the surgery.[178] It is not clear to what extent this applies to patients who present with EGS diagnoses, as many of these patients are frail or malnourished. The optimal balance to improve survival between a delay to improve nutrition prior to a definitive procedure and rapid correction of the primary diagnosis has yet to be determined.

Many of the frailty indices include significant weight loss as an important contributor to the frailty severity. The more frail a patient is, even if it is related to malnourishment, the more likely they are to have complications after emergent surgery. It is therefore also reasonable to believe that laparoscopy or damage control principles portend better outcomes in the severely malnourished patients. Ultimately, however, there are not definitive data that malnourished patients have better outcomes with a laparoscopic approach in the acute setting.

Coagulopathic patients

When laparoscopic surgery was in its early stages, there was concern about the ability to safely manage patients with an increased risk of bleeding because it was believed that hemorrhage control was more difficult to achieve laparoscopically. As techniques and technology have improved over the last 25 years, so too has the confidence of surgeons who operate on patients that may be at increased risk of bleeding. Assuming there is solid surgical technique, bleeding does not occur at a higher rate with laparoscopic surgery than with open techniques, even in coagulopathic patients.[104,179,180] There also do not appear to be worse bleeding outcomes with MIS techniques in the EGS setting.[1,181] Thus, the available evidence for management of coagulopathy in emergency surgery should apply to both laparoscopic and open techniques.

Coagulopathy occurs through one of two mechanisms: from underlying diseases such as cirrhosis, uremia, or thrombocytopenia, or from medications such as direct oral anticoagulants (DOAC), antiplatelet therapy, or injection of heparin products. Neither of these 2 mechanisms are easy to reverse in the acute setting. The management of patients in the acute setting who are taking anticoagulants depends on the half-life of the medication, the availability of reversal agents, and the risk of a thrombotic/ischemic event if the medication is stopped or reversed (Table 15).

In the EGS setting, there may not be enough time to withhold an anticoagulant to achieve normal coagulation prior to surgical intervention. As such, active reversal often has a more significant role in EGS cases. It is important to note that there is no generally agreed upon goal for reversal; and active reversal in the non-surgical literature mostly describes reversal for over anticoagulation (INR [International Normalized Ratio] $>$ 6) due to the risk of spontaneous bleeding, with a goal to keep the INR still greater than 2. This may not be adequate for the management of surgical bleeding.

Medically-induced coagulopathy

Warfarin is a vitamin K antagonist with a half-life of approximately 50 hours.[182] Consequently, it is important to consider reversal in patients who require urgent and emergency procedures. For vitamin K antagonists, the favored reversal agent is 4-factor prothrombin complex concentrate (4F-PCC, Kcentra) rather than fresh frozen plasma (FFP). This is because 4F-PCC results in less volume overload.[183] Vitamin K is also recommended to help with the reversal as this medication alone will correct 45% of patients within 6 hours.[184] Oral and IV vitamin K are better suited for management of elevated INR as subcutaneous vitamin K is less effective.[185] The American College of Chest Physician guidelines recommend 10 mg of vitamin K administered IV

Table 15
Characteristics of anticoagulation medications.

	Mechanism	Half-life	Reversal agent
Direct oral anticoagulants (DOACs)			
Warfarin (Coumadin)	Vitamin K antagonist, preventing activation of CFs II,VII, IX, X, protein C, protein S	90 h	4F-PCC
Dabigatran (Pradaxa)	Thrombin (CF IIa) inhibitor	12-17 h	3F or 4F-PCC Hemodialysis Idarucizumab
Rivaroxaban (Xarelto)	CF Xa inhibitor	9-13 h	4F-PCC Andexanet Alfa
Edoxaban (Lixiana/Savaysa)	CF Xa inhibitor	8-10 h	4F-PCC
Apixiban (Eliquis)	CF Xa inhibitor	8-15 h	4F-PCC Andexanet Alfa
Heparins			
Unfractionated heparin	Binds with anti-thrombin III to inhibit CFs IIa (thrombin), Xa, IXa, XIa, and XIIa	1-1.5 h	Protamine sulfate FFP
Enoxaparin (Lovenox)	Binds with anti-thrombin III to inhibit CFs IIa (thrombin), Xa, IXa, XIa, and XIIa	4.5 h	Protamine sulfate FFP
Dalteparin (Fragmin)	Binds with anti-thrombin III to inhibit CF IIa (thrombin), Xa, IXa, XIa, and XIIa	2-4 h	Protamine sulfate FFP
Tinzaparin (Innohep)	Binds with anti-thrombin III to inhibit CFs IIa (thrombin), Xa, IXa, XIa, and XIIa	1-4 h	Protamine sulfate FFP
Fondaparinux (Arixtra)	CF Xa inhibitor	17-21 h	FFP
Antiplatelet Therapy			
Aspirin	COX-1 inhibitor	7-10 d	Not needed
Dipyridamole	COX-1 inhibitor	7-10 d	Not needed
Aspirin/Dipyridamole (Aggrenox)	COX-1 inhibitor	7-10 d	Not needed
Clopidogrel (Plavix)	Prevents P2Y12 receptor from binding with ADP	6 h	Platelet transfusion Desmopressin
Ticlodipine (Ticlid)	Prevents P2Y12 receptor from binding with ADP	12 h	Platelet transfusion Desmopressin
Prasugrel (Effient)	Prevents P2Y12 receptor from binding with ADP	7 h	Platelet transfusion Desmopressin
Ticagrelor (Brilinta)	P2Y12 receptor antagonist	6-13 h	Platelet transfusion Desmopressin
Eptifibatide (Integrilin)	GPIIb/IIIa inhibitor	2-4 h	Not needed
Tirofiban (Aggrastat)	GPIIb/IIIa inhibitor	2-4 h	Not needed

CF, clotting factor
3F, 3-factor
4F, 4-factor
FFP, fresh frozen plasma
COX, cyclooxygenase
ADP, adenosine diphosphate

as first line therapy.[182] Whether 4F-PCC is needed in addition should be determined based on the severity of the anticoagulation and the urgency of operative intervention.

Newer DOACs have the advantages of shorter half-lives and more predictable responses to reversal. Yet there is no standard method for monitoring the coagulation status of the newer DOACs such as dabigatran and rivaroxaban. The INR and levels of prothrombin time (PT) and activated partial thromboplastin time (aPTT) are not universally reliable in assessing the coagulation status of a patient. In general, 4F-PCC or 3F-PCC are recommended for reversal of DOACs because of the lower volume of fluid transfused.[186] Unlike FFP, they do not require being stored

in a frozen state, which can delay transfusion. PCC is clotting factors II, IX, and X with a variable amount of VII (more for 4F and less for 3F) to help mitigate the risk of thrombosis.[186]

Dabigatran levels can be measured using mass spectrometry, a diluted thrombin time, and an ecarin clotting time (ECT). None of these are likely to be available at most hospitals and even less likely to be available emergently. A normal thrombin time does indicate that there is minimal dabigatran present in the serum. The recommended reversal agent is 4F-PCC or idarucizumab (Praxabind). Idarucizumab is a monoclonal antibody that binds to dabigatran to reverse its effects. The REVERSE-AD trial shows that idarucizumab is very effective in fully reversing dabigatran in emergent situations with minimal thrombotic events.[187]

Apixaban, edoxaban, and rivaroxaban are clotting factor (CF) Xa inhibitors used for stroke prevention and venous thromboembolic prophylaxis. A normal PT level indicates complete clearance of these inhibitors, but there are no readily available tests for CF Xa inhibitor concentration in the serum. 4F-PCC is the currently favored reversal agent for emergent situations.[186] The ANNEXA-4 trial tested andexanet alfa (Andexxa) as a CF Xa decoy that can block a CF Xa inhibitor. The trial showed that apixaban and rivaroxaban levels can be approximately 90% decreased with good clinical hemostasis. There is still an associated thrombotic event rate of approximately 18% over the next 30 days.[188]

Heparins bind with anti-thrombin III to inhibit the function of CFs IIa, IXa, XIa, and XII and its effects can be reliably measured by the aPTT. Protamine is a reversal agent of heparins and it has been described for use in emergency situations. The effects of protamine are varied and only partially effective.[189] In urgent cases, the half-life of the heparins ranges from 1.5 hours-4 hours and so a few hours may be all that is needed to control bleeding. It should be noted that fondaparinux (Arixtra) has a long half-life of 17-21 hours, so it may require reversal. In emergency situations, when protamine does not work, or when the bleeding is attributed to fondaparinux, FFP is recommended to treat the bleeding.

Antiplatelet medications

Antiplatelet medications work by one of 3 mechanisms: cyclo-oxygenase 1 (COX-1) inhibition, P2Y12 inhibition, or GPIIb/IIIa inhibition. Acetylsalicylic acid (aspirin) permanently inactivates the COX-1 enzyme to prevent platelet aggregation. The effect lasts the lifetime of the platelet, roughly 7-10 days. Most operations, even emergency ones, can be conducted safely in patients who are taking aspirin.

P2Y12 inhibitors block the interaction of the platelet's adenosine diphosphate with the P2Y12 receptor. This interaction (when not blocked) activates the GPIIb/IIIa receptor which causes platelet aggregation.[190] The P2Y12 inhibitors include clopidogrel (Plavix), prasugrel (Effient), and ticlodipine (Ticlid). The P2Y12 inhibitors have half-lives that range from 6 to 12 hours, but the effects of these medications can last up to a week. There is evidence that urgent operations can proceed safely while patients are on P2Y12 inhibitors without a risk of mortality or significant morbidity.[191]

The direct GPIIb/IIIa inhibitors include eptifibatide (Integrilin) and tirofiban (Aggrastat). Emergency cardiac surgery does not see increased bleeding and morbidity for patients taking these medications.[192,193] There are scant data on the risk of bleeding in patients undergoing emergency non-cardiac surgery while on GPIIa/IIIb inhibitors, but these agents have a short half-life of 2-4 hours. Furthermore, although they have efficacy in the prevention of acute coronary syndromes, they have fallen out of favor to the P2Y12 inhibitors instead.[194]

A discussion about dual antiplatelet therapy for stents is covered in the section about cardiac disease, but in general, patients with drug eluting stents that have been placed less than 6 weeks ago should continue both therapies, if possible. If not, then at least aspirin should be continued. If reversal is needed because of life-threatening bleeding, then platelet transfusion and desmopressin should be given. This will, however, raise the risk of cardiac complications.[195]

Coagulopathic diseases

Cirrhosis is a particularly worrisome condition for surgery patients, in part because of the risk of bleeding. One challenge with cirrhosis is that these patients are at risk for both bleeding

and thrombotic events. Additionally, it is hard to measure and hard to predict either of these events. The INR, PTT, and aPTT tests do not accurately predict the cirrhotic patient's ability to form clot. Thromboelastography, which evaluates how well the patient's platelets and clotting factors function, is recommended to evaluate the ability of the patient to form clots to guide transfusion. Typically, transfusion to prevent bleeding in cirrhotic patients should not be given but should be used if active bleeding is encountered intraoperatively. Transfusion should also be guided by the results of the thromboelastography.

The stress of an emergency surgical procedure can turn compensated cirrhosis into uncompensated cirrhosis, meaning the patient can go into acute liver failure, resulting in increased bleeding. Although cirrhotic patients undergoing elective surgery have increased morbidity compared to non-cirrhotic patients, procedures should still be performed in the elective setting, when possible. In surgical patients with cirrhosis, bleeding is unlikely to be the only complication caused by the liver disease. The risk of both morbidity and mortality of surgical procedures can be estimated by the Child's-Pugh classification (A through C) and the Model for End-stage Liver Disease (MELD) score. For the most part, MELD scores less than 12 correspond to Child's class A and are considered low risk for surgery. MELD scores from 12 to 19 correspond to Child's class B and are considered moderate risk. MELD scores greater than 20 are considered high-risk, corresponding to Child's class C, which carries a predicted mortality rate of 40%.[196] Further increases in MELD scores correspond to an even higher predicted mortality rate.

Surgical procedures performed in the emergency setting have an even higher rate of morbidity and mortality. Varices are common in cirrhotic patients and can contribute to perioperative bleeding. Consideration should be given to decompressing the varices using transjugular intrahepatic portosystemic shunting (TIPS) to decrease bleeding, even in the urgent setting. This can also decrease ascite,s which can result in decreased incidence of wound complications. When possible, patients with significant cirrhosis may benefit from transfer to a hospital that has a multidisciplinary team to manage liver failure and evaluate patients for possible transplantation.

Laparoscopy and endoscopy are safe in patients with cirrhosis and in the elective setting may show reduced infection rates. However, laparoscopy has not demonstrated fewer wound complications, including ascitic leak, or bleeding complications.[197,198] Port placement should be well thought out to avoid injury to abdominal wall varices, which can be very difficult to control laparoscopically.

There are some data comparing open versus laparoscopic approaches in acute situations. Laparoscopic appendectomy is recommended in patients with both compensated and uncompensated cirrhosis, even though the latter still carries high morbidity and mortality. A retrospective database review concluded that the laparoscopic approach was still superior to both the open approach and medical management.[199] In one meta-analysis of patients with cirrhosis undergoing laparoscopic cholecystectomy, 17% of the patients underwent emergent operation and overall, Child's A and B class patients fared better with the laparoscopic approach, showing less blood loss, shorter operative time, and shorter hospital stays. The overall mortality, however, was the same compared to the open group.[181] For Child's class C patients, there are very few data, but these patients have a mortality risk up to 75% and thus, percutaneous cholecystostomy tubes or other nonoperative management are recommended. The radiologist may be wary of performing this procedure in the decompensated patient and a laparoscopic cholecystostomy tube may be required.[200]

Renal failure and uremia

It is not entirely clear why uremia causes platelet dysfunction, but uremic patients are at an increased risk of bleeding complications. The bleeding risk in these patients is often already increased due to concomitant administration of other antiplatelet medications. In general, patients with uremia can be treated preoperatively with desmopressin to help prevent bleeding in patients undergoing a procedure.[201] If surgery can be delayed, then dialysis prior to surgery may be helpful to reduce the risk of bleeding, but it does not eliminate this risk.[202]

Clotting factor deficiency

Patients can present with clotting factor deficiencies, of which the most common deficiencies are vonWillebrand factor (vWF), clotting factor VIII (hemophilia A), and clotting factor X (hemophilia B).[203] For patients who have previously received clotting factor transfusions, subsequent transfusions may not be as effective due to antibodies that act as inhibitors created from the prior transfusion.[204] For those patients with von Willebrand's disease, desmopressin and vWF-containing concentrates such as cryoprecipitate can be administered prior to emergency surgery. For patients with hemophilia A or B, the corresponding factor deficiency is administered prophylactically.[204] Alternatively, and in patients with antibody inhibitors, recombinant clotting factor VII and activated PCC (CFs II, VII, IX, and X) can be administered with similar efficacy in bleeding control.[205] For the other more rare CF deficiencies, FFP or PCC can be administered prophylactically to assist with bleeding control.[204]

Summary

In general, the risks of acute care surgery are increased in patients with a coagulopathy whether it be medically-induced or due to a disease such as cirrhosis or hemophilia. It does not appear that MIS techniques increase the risk of bleeding and thus are not any riskier than open procedures in this patient population. At the same time, there are no studies directly comparing the 2 approaches in the coagulopathic patient. The correction of the coagulopathy should be accomplished as part of the initial resuscitation of these patients prior to proceeding with surgery, in the case of the coagulopathy being due to a vitamin K antagonists, heparin, uremia, or the hemophilias. Patients taking antiplatelet agents can usually proceed to surgery, with transfusion reserved for patients who show clinical signs of bleeding. In the case of cirrhosis, the degree of coagulopathy should be determined by thromboelastography and everything, to include percutaneous and endoscopic procedures, should be done to avoid emergent surgery. Emergent TIPS can be performed in those patients whose emergency surgery cannot be avoided, although this is not available in every hospital.

MIS in frail patients

Frailty, by strict definition, is a patient's diminished capacity to respond to external stress.[206] It is a physical and physiologic condition that can be defined by several factors. More so than age, it is the amount of frailty that increases patients' susceptibility to morbidity and mortality. It is not necessarily just poor cognitive ability or limited activity due to a chronic disease like osteoarthritis, but those can also add to the patient's frailty. Frailty is not limited to the elderly and it can occur in any adult patient.

Defining and measuring frailty is controversial, and there are several frailty scores or indices in use. The Edmonton Frail Scale measures cognition, general health status, functional independence, social support, medication use, nutrition, mood, continence, and functional performance. It asks the patient to draw hands on a clock and it times the physical task of getting up from a chair, walking 3 meters, and returning to the chair. The latter would be impractical for a patient with an acute abdomen to do and the pain may falsely label the patient as higher risk.

Other indices have been created specifically for surgical patients. Using a 15-variable index specifically for EGS cases, the EGS frailty index (EGSFI) noted a morbidity odds ratio of 7.3 for frail patients compared to non-frail ones.[207] A more recent study outlined an 11-factor ACS-NSQIP frailty score that only included objective criteria.[208] Investigators estimated a 19% mortality rate in the highly frail patients undergoing EGS procedures, including procedures such as a cholecystectomy. One criticism of the study was that the highly frail patients underwent more complex operations, and colon resection was the most common procedure in this population. Efforts at simplifying the assessment of frailty have led to creation of a 5-factor frailty index using the ACS-NSQIP data, which was demonstrated in this study to be as accurate as the 11-factor one.[209] One feature that all of these scales had in common was that high frailty was associated

with worse outcomes and the higher the patient's frailty score, the more likely were complications.

Another issue with many of the frailty scales is that there is subjectivity to the grading. Some indices ask for self-reported poor energy and endurance. Another asks if patients feel sad, feel less useful, and feel lonely. The Murphy modified 11-point frailty index uses only objective data, but it is not specific for EGS patients, and the EGSFI[207] had very subjective criteria. To date, there is no single index that encompasses purely objective data to assess the amount of frailty for EGS patients.

One objective measure of frailty is sarcopenia. Sarcopenia can be measured using CT, magnetic resonance imaging (MRI), whole-body dual-energy X-ray absorptiometry (DXA), or bioelectrical impedance. For the EGS patient, the most practical method would be CT. It can also be measured using the average area of the psoas muscles at L3 on CT divided by the patient's body surface area (BSA) using the formula:

$$BSA\ (m^2) = \sqrt{\frac{[height\ (cm) x\ weight\ (kg)]}{3600}}.$$

So L3 skeletal muscle index (SMI) would be the area of the psoas muscle at L3/BSA. For men, a L3-SMI of less than 52.4 cm/m^2 and for women, a L3-SMI of less than 38.5 cm/m^2 indicates sarcopenia.[210] It should be noted that there are different parameters of low skeletal muscle indices by the different modalities. It should also be noted that obese patients can be sarcopenic as it not a condition reserved for low body-mass index (BMI) patients. Finally, sarcopenia defined by low muscle mass is associated with poorer operative outcomes,[211] likely regardless of the definition.

Whatever frailty scale is used, though, there is no doubt that increased frailty predicts increased morbidity and mortality after surgery. The interactive effect of frailty and EGS combined is likely underappreciated. It should come as no surprise that emergency operations are an independent risk factor for poor outcomes in frail patients.[208,212] The risk of mortality in highly frail patients undergoing EGS ranges from 4% to 22%. Furthermore, the risk of postoperative complications, including death, increases with the scaled estimate of frailty.[213] Finally, most studies define the frailty categories as high, intermediate, and low frailty, with the high frailty associated with increased mortality whereas intermediate frailty is only associated with increased morbidity, and low frailty patients equivalent to their non-frail counterparts for acute care surgery. On average, high frailty is associated with a morbidity rate of approximately 25% and a mortality rate from 19% to 22%, meaning these patients are twice as likely to have a complication and 4 times as likely to die than non-frail or low frailty patients.[207,208,214] It should also be noted that highly frail patients are discharged to rehabilitation facilities up to 70% of the time.

Cancer patients needing emergency surgery probably represent a subpopulation that is at even greater increased risk for complications. Some studies have proven that even long-term survival is worse in cancer patients who are frail. Sarcopenia may have something to do with this increased morbidity and mortality. In the elective setting, frailty in cancer patients who need surgery is associated with poorer 5-year outcomes.[215] For the more complicated emergent procedures such as a bleeding gastric cancer, a ruptured gallbladder cancer, or a perforated colon malignancy, it seems logical that these patients would fare poorly from the combination of their cancer, their emergency procedure, and their frailty diagnosis.

Geriatric care

The elderly are the fastest growing population in the United States. Elderly patients often have an increased number of chronic diseases, which likely contributes to the incidence of frailty amongst the elderly population. The aforementioned ACS-NSQIP calculator has the ability to also incorporate geriatric factors into a calculation to predict the morbidity and mortality related to the patient's frailty along with his or her other medical comorbidities and the risk of the procedure. It can also provide an estimate of the likelihood a patient will need rehabilitation and the likelihood the patient will not be able to achieve functional independence. The ACS-NSQIP calculator also predicts the chance of postoperative delirium, the need for new mobility aid use,

pressure ulcers, and functional decline. It is important to remember, though, that age alone is not a risk factor for these outcomes. Better outcomes are obtained with dedicated geriatric consult services and these should be employed, when available, regardless of the patient's frailty.[216]

Frailty and minimally invasive surgery

There are several studies identifying the safety of MIS techniques in EGS for frail patients. An Italian study published in 2020 on 1993 EGS patients showed that frailty was associated with increased morbidity and mortality; and secondary analysis on the open versus laparoscopic approach showed a significant difference in morbidity (36.2% vs 22.1%) and mortality (11.2% vs 2.2%), favoring the minimally invasive approach.[217] Follow-up studies from the same Italian group on individual diseases such as PUD do not show the same significant difference in mortality for frail patients, but better results were noted with decreased blood loss, length of stay, and operative time.[218]

A NSQIP database study on laparoscopic cholecystectomy for acute cholecystitis identified that intermediate frailty on the multidimensional fatigue inventory (MFI) scale was associated with an odds ratio of 1.81 for a Clavien-Dindo IV morbidity and an odds ratio of 4.69 for mortality, while high frailty is associated with an odds ratio of 4.59 for a Clavien-Dindo IV morbidity and an odds ratio of 12.2 for mortality.[219] As such, the best option in these high frailty patients is probably to manage them nonoperatively, if possible. Moderate or severe Tokyo class cholecystitis may be better treated with a laparoscopic or percutaneous cholecystostomy tube until some modifiable frailty risk factors can be improved. Gallstone pancreatitis may be better treated by ERCP/sphincterotomy only or by waiting several weeks to months after ERCP rather than early cholecystectomy, which is beneficial in less frail patients.

MIS techniques may have the greatest impact in the intermediately frail patients, who can be converted to a semi-urgent procedure or watchful waiting. The surgical goal may be damage control rather than definitive care in certain situations. Hinchey III diverticulitis may be better treated by a laparoscopic washout as opposed to a colonic resection, diverting ileostomy, and primary anastomosis.[220]

For incarcerated paraesophageal hernias, a laparoscopic reduction, gastropexy, and G-tube placement may be all that is needed initially, and sometimes that may be all that is needed for definitive management. There is a potential that the paraesophageal hernia may recur because the hernia is not fixed, but that can often be addressed with formal repair at a later time and ideally electively if the patient's frailty can be improved. In the meantime, the laparoscopic or endoscopic procedure has the ability to stabilize the acute situation.

Although there are some data showing that laparoscopy is superior to the open approach in frail patients undergoing more complex operations like a colonic resection,[221,222] these studies did not always consider that an emergency procedure was being performed. As such, there are not definitive data that MIS alone is superior to open surgery for acute issues in the frail population.

Summary

Frailty should be estimated preoperatively in patients undergoing EGS. This can help the patient or family decide how best they would like to proceed, especially if the surgery is likely to result in death or inability to extubate. It can help dictate what the best options are for the surgical approach and surgical goals in the high-risk patients. Finally, it should be re-emphasized that frailty is not determined by age. Frailty has to do with the comorbidities of patients and their functional status; and it is the degree of frailty that is positively associated with poorer outcomes.

Pregnancy

For any approach, surgical intervention in pregnant patients is generally considered safest in the second trimester. The first trimester carries a risk of impacting organogenesis or spontaneous

abortion, while the third trimester has an increased risk of inducing labor and early delivery.[223] Acute appendicitis and acute cholecystitis are the most common EGS diagnoses that require a non-gynecological operation during pregnancy.[223] In 2017, SAGES provided an excellent guideline on the topic of laparoscopy during pregnancy which includes detailed information on preoperative evaluation, including imaging modality.[223] Based on available evidence, both SAGES and the 2019 British Society for Gynaecological Endoscopy (BSGE)[224] recommend that laparoscopy is safe during any trimester without increased risk to the mother or fetus,[223,224] although this continues to be an active area of research.[225] The BSGE reports that small series have reported good outcomes for laparoscopic procedures up to 34 weeks gestation.[224]

Technique

Pregnant patients should be positioned on the OR table in the left lateral decubitus position to offload the uterine pressure from the inferior vena cava.[223] Abdominal entry can safely be accomplished by any of the techniques routinely used in laparoscopy (open, Veress needle, or optical trocar) if adjusted according to fundal height.[223] Fundal height can be determined by palpation in most cases, but in patients who are morbidly obese or with other pathology that makes this challenging, should be confirmed by US.[226] Our group's preference is to obtain access either the LUQ or the right upper quadrant (RUQ), depending on anatomy and surgical history, locations recommended by the BGSE[224] to avoid injury to the gravid uterus. We most commonly use a cutdown technique under direct visualization due to the displacement of abdominal organs in the setting of pregnancy.

After initial abdominal entry has been obtained, the abdomen is insufflated. The BGSE recommends insufflation pressures of 12 mmHg.[224] We tend to use an insufflation pressure of 12 mmHg to avoid additional caudal displacement of the diaphragm, and generally find that this affords adequate visualization. When needed, pressures of 15 mmHg have been used safely (SAGES).[223] Placement of additional ports should be under direct visualization and the location will depend on the operative targets. A "no touch" approach of the uterus is recommended by the BSGE due to the increased friability of the uterine surface during pregnancy.

Postoperative management should include appropriate pain control, as needed, early ambulation, and postoperative fetal monitoring.[227] In our practice, fetal heart tones are not monitored intraoperatively, but are obtained in the recovery room by an obstetric nurse consistent with recommendations. Opioids can be administered safely, but nonsteroidal anti-inflammatory drugs (NSAIDs) are recommended to be avoided.[227]

Malignancy

Although many cases of malignancy are able to be assessed electively, there will remain a subset of patients who either have (1) a known malignancy and a concurrent acute care surgery diagnosis or; (2) who present with a previously undiagnosed malignancy requiring same-admission intervention. In patients with a known malignancy and an acute care surgery diagnosis, the overall management course will require a careful weighing of risks and benefits of available options, ideally in conjunction with the patient's oncologist. This discussion should factor in overall prognosis, treatment options, immunosuppression if actively undergoing treatment, and patient goals of care. If surgical management is the best option in this setting, there are no absolute contraindications to laparoscopy due solely to the presence of malignancy. For example, our group has had success with the laparoscopic approach to PUD in patients who have a perforation while receiving chemotherapy. A not uncommon challenge to the laparoscopic approach in this scenario is the finding of carcinomatosis that hinders adequate visualization and the ability to adequately maneuver tissue to complete the desired procedure. In these cases, either conversion to an open procedure or abortion of the planned procedure will be necessary. One benefit of the initial laparoscopic approach includes the ability to assess if an open approach will be successful, and in cases where it is not, to avoid the postoperative pain associated with a laparotomy.

Patients with a previously undiagnosed malignancy most commonly present in the acute setting with bleeding, obstruction, or perforation. The use of endoscopy in the setting of malignancies is routine and can include assessment and diagnosis as well as management (such as stenting). For most malignancies, curative intent requires a more invasive approach than endoscopy.

In the initial years of increased uptake of laparoscopy in elective cases, there was concern about its safety in the setting of active malignancy. In the interim, it has generally been accepted to be safe in the setting of elective surgery for malignant disease as long as the principles of open surgery are followed (adequate anatomic resection) and appropriate protection against abdominal wall implants at port sites. The minimally invasive approach, both laparoscopic and robotic, is now routinely accepted as safe in the management of many malignant diseases, with colon cancer having the greatest evidence base to support the minimally invasive approach.[228]

As the use of laparoscopy spread to acute care surgery, patients with malignancies were sometimes excluded.[229] However, as long as the principles of adequate oncologic resection (when feasible and part of the goal of the procedure) and appropriate protection against abdominal wall implants is utilized, there are no absolute contraindications to minimally invasive approaches for a patient with malignant disease and an acute care surgery diagnosis. Techniques recommended to prevent wound complications, including abdominal wall cancer recurrences, include the use of a wound protector at the extraction site and irrigation of port sites and extraction site incisions.[14] Examples of successful uses of MIS in the setting of malignancy include venting gastrostomy tubes in patients with non-resectable SBOs due to cancer[230] and laparoscopic colostomy in the setting of non-resectable obstructing colon mass.[231] Endoscopy can also play an important role in the acute management of malignancy, such as stenting in obstructing colon cancer and esophageal malignancies that manifest with obstructive symptoms or perforation.[232]

Defining quality in MIS acute care surgery

The discussions above summarized the data about the use of MIS with certain diseases and for certain patients. In this section, we discuss what we feel are the essential knowledge and skills needed to perform MIS safely and how surgeons should measure their success when treating acute care surgery patients. We also discuss how we should define high-quality and safe care in the use of MIS techniques for acute care surgery. For this purpose, the techniques of robot-assisted laparoscopic surgery and single incision laparoscopic surgery fall under the purview of these MIS techniques, as physiologically there is no known difference to the patient with these other MIS approaches. As such, for now, the quality and expected outcomes should be the same, regardless of the approach.

The importance of the Fundamentals of Laparoscopic Surgery and Fundamentals of Endoscopic Surgery courses

For general surgeons who wish to practice laparoscopic surgery, it is recommended to have an understanding of the basics of laparoscopic surgery both cognitively and practically. The Fundamentals of Laparoscopic Surgery (FLS) program was designed to demonstrate competency in laparoscopic surgery. Since 2014, any graduating resident must pass the FLS test in order to qualify for the American Board of Surgery certification examination. Similarly, starting in the spring of 2021, graduating OB-GYN residents will also require successful passing of the FLS in order to be certified by the American Board of Obstetrics and Gynecology.

The FLS program consists of 4 didactic modules and 1 module on manual skills (Table 16). Passing the FLS test includes passing a written test and passing the manual skills test, proctored by a non-surgeon. The didactic skills can be learned via the online modules. The learner will need to practice the manual skills portion in order to pass.

Table 16
Technical skills of the Fundamental of Laparoscopic Surgery (FLS) course.

Peg transfer
Precision cutting
Ligating loop
Suture with extracorporeal knot tying
Suture with intracorporeal knot tying

Although FLS certification is not needed to practice laparoscopic surgery or for surgical credential approval for surgeons who graduated before 2014, gaining its certification indicates the learner has the basic knowledge and skills to perform laparoscopic surgery safely. Simulator training and the skills learned via FLS have been shown to improve performance in the OR.[233,234]

In addition to the necessary skills to show competence, the FLS program addresses topics such as the physiologic effects of laparoscopy, gaining intra-abdominal access safely (including in patients who have had previous surgery), and the safe use of equipment. Safe use of surgical energy is addressed in the next section.

Regarding intra-abdominal access and establishing a pneumoperitoneum, there are 3 common methods: the Veress needle technique, the open Hasson trocar technique, and the optical viewing technique. No single method has been demonstrated to be superior to another in terms of avoiding injury and being successful. Surgeons should be familiar with all of the techniques as some patients may fare better with one technique over another. In patients with a previous surgical incision, especially multiple ones, the open technique is recommended by the authors and it should be performed at least 5 cm away from another incision when possible. One advantage of this technique is direct visualization upon entry into the abdomen so injuries can be recognized immediately. Another advantage is that blunt finger dissection can be performed to reduce surrounding adhesions, allowing for better initial visualization for the pneumoperitoneum. The Veress needle technique allows for establishing the pneumoperitoneum through a small incision which is beneficial in obese patients who may require an incision of 3 to 5 cm to reach the peritoneum if there are several layers of adipose tissue. The optical view technique also allows for abdominal access without a large incision but creates a larger tract than the Veress needle. In obese patients, another commonly used technique is to establish the pneumoperitoneum using a Veress needle technique first and then using an optical viewing port to enter the abdomen after the pneumoperitoneum has been established. Placing the patient in a slight reverse Trendelenburg position allows gravity to pull excess adipose tissue away from the upper abdomen, enabling easier access with a Veress needle or optical viewing port.

The umbilical region is an area commonly used for access with a Veress needle or optical viewing port, however one must be cognizant of this entry in patients who are thin or lean. The inferior vena cava is only about 2-3 cm away from the umbilicus when patients are supine. Any downward pressure in these areas can put the Veress tip right up against the IVC, resulting in a devastating injury, even if the surgeon is lifting up the abdominal wall. The authors recommend using Palmer's point, approximately 1 cm below the left sub-costal margin in the mid-clavicular line to place the Veress needle. Proper position of the needle should be confirmed by an opening intra-abdominal pressure of less than 10 mm Hg. Then the surgeon can use an optical viewing port in another position to gain the first visualization of the abdomen. The pneumoperitoneum can add a few extra centimeters to the distance between the anterior abdominal wall and the retroperitoneum.

The authors recommend that surgeons who care for acute care surgery patients be certified in FLS. This will provide surgeons with the necessary knowledge and skill to increase the chances of being successful even in the acute abdomen with diseased tissue planes. The authors advocate that all laparoscopic surgeons use simulation to practice advanced maneuvers and that surgeons have multiple options available to perform advanced laparoscopic maneuvers. For in-

stance, surgeons who use laparoscopy should be comfortable tying knots intracorporeally using a standard suture as well as the Endo Stitch device (Medtronic). Surgeons should also know how and when they can use an extracorporeal technique.

The certification of the Fundamentals of Endoscopic Surgery (FES) course is similar to FLS in philosophy and purpose. It is used to define competency in the use of endoscopy. Since 2018, graduating residents are required to pass FES in order to earn certification from the American Board of Surgery. The didactic portion is more extensive than FLS as it discusses upper endoscopy, lower endoscopy, and advanced endoscopic techniques. The didactics also discuss enteral access and procedures like ERCP and choledochoscopy. Unlike FLS, the surgeon is not expected to be competent in these skills after completing the FES certification, but they should be familiar with them. The manual skills portion of FES involves being able to perform endoscopy, tissue acquisition, and hemostasis. The authors recommend that surgeons who care for acute care surgical diagnoses be certified in FES if they are going to use MIS techniques for these patients. The FES concepts could then be the basis for performing therapeutic endoscopy, including hemorrhage control, stricture dilation, stenting perforations, and dislodged G-tube management. These maneuvers should be well within the surgeon's armamentarium as they treat complicated patients in both the trauma and EGS fields.

In general, certification in FLS and FES is valuable for surgeons caring for acute care surgery patients. This should help surgeons in their ability to apply laparoscopic and endoscopic techniques for these patients.

FUSE: Fundamental use of surgical energy

There are basic skills one must obtain in order to safely perform laparoscopic and endoscopic surgery. Similarly, surgeons performing laparoscopic surgery must have a basic understanding of the use of surgical energy in order to prevent injuries from its use and to use the instruments properly. If a surgical energy injury occurs in an open procedure, often the surgeon will be able to see it right away and have easy access to repair it. This can be very different in laparoscopic or endoscopic surgery. An injury may occur off the screen and as such, may not ever be seen by the surgeon or may not be in an area that is easily accessed by the surgeon.

Most studies comparing laparoscopic to open surgery in the acute setting do not show an increased rate of injury with the MIS approach.[1] Similarly, previous abdominal operations do not seem to increase the amount of abdominal injuries as it pertains to approach. Injuries to organs that do occur can be due to aggressive dissection, inadequate exposure, or lack of experience; but they can also be secondary to the electricity in surgical devices. In fact, an estimated 40,000 burns occur annually from surgical energy injuries, with approximately 70% of these injuries happening in laparoscopic cases.[235] More than one half (54%) of surgeons say that they personally have had or know of a colleague who had a surgical energy injury and 18% of surgeons report that they have had one themselves.[236] This injury is perhaps more common than expected.

Fortunately, a basic understanding of surgical energy can help prevent these injuries. Today, there are several commercial modes of surgical energy that are commonly used. In addition to the mode of energy and the equipment used, the surgical technique can also contribute to the risk of electricity related injuries. For any surgeon using surgical energy in the OR, an understanding of how the devices work is paramount (Table 17).

Monopolar energy

Monopolar energy is the most commonly used form of surgical energy and it is often mistakenly called "cautery." Cautery, though, is the transfer of heat, like an iron. With monopolar surgical energy, electricity is passed from the wall socket to the energy device, amplified, and then extended to the tip, as with a Bovie pencil (Bovie Medical) or an L-hook in laparoscopy. This tip represents 1 pole. This electrical energy is then transferred to the tissue by touching the tissue. This energy then tends to transfer to the other pole, in this case the dispersion pad,

Table 17
Important temperatures and characteristics of surgical energy use.[160]

	Temperature	Latent period	Vessel control
Cell	38° C		
Cell damage	50° C		
Monopolar cut mode	90-110° C	3-4 sec	3-4 mm
Monopolar coag mode	60° C	3-4 sec	2-3 mm
Bipolar	100-110° C	3-4 sec	2-3 mm
Advanced bipolar devices	100-110° C	3-4 sec	7 mm
Ultrasonic	>200° C	20-30 sec	5 mm

which is commonly, but erroneously, called the grounding pad. Any tissue between those 2 poles can become injured. Generally, the tissue resistance limits the damaging effects of the electrical energy to the surface in contact with the tip of the instrument, however prolonged or repeated contact can overcome the resistance.

The electrical energy inside the tissue causes its molecules to vibrate, which in turn creates heat. It is this heat which causes tissue destruction. The more powerful the electrical energy going to the tissue, the more heat which is generated and the deeper the effect of the energy transferred. The "cut" mode has higher power, thus deeper penetrance through the tissue, allowing the instrument to dissect through the tissue. The "cut" mode achieves higher power by being a continuous transfer of current. The continuous current can cause the cell to achieve temperatures of 90°-110° C. Since tissue destruction begins at 50° C, these temperatures cause deeper destruction of the tissue, allowing deeper dissection. The "coag" mode has lower power and less penetrance, allowing it to denature proteins at the surface, which forms a coagulum that helps to stop bleeding. The "coag" mode only transfers current 4%-6% of the time it is on and thus only achieves temperatures of approximately 60° C. This limits the tissue destruction to the surface cells and creates a coagulum instead of penetrating the surface deeper.

Monopolar devices do not transfer heat or cauterize. The transfer of heat, like a hot iron, can achieve the same results as coag mode, destroying the surface cells and creating a coagulum, but only in the areas that are directly in front of the surgeon. Monopolar instruments transfer electric current and thus any point along the instrument that is not insulated or that comes into contact with tissue can cause the electrical current to be transferred to that tissue. Consequently, the transfer of energy can occur in areas where the surgeon is not looking. In laparoscopic instruments, stray electrical current can escape through damaged laparoscopic insulation, even if the damage is not visible to the naked eye.[237]

Bipolar energy

In bipolar instruments, the energy again travels from the wall socket to the electrosurgical generator where it is amplified, down to the instrument, and to the tissue. Here, though, the second pole is not the dispersion pad but rather the other prong of the instrument. So energy does not travel through the body as with monopolar energy, it only transfers energy to the tissue that is between the 2 prongs of the instrument. Bipolar instruments can achieve temperatures to 100° C, but because the energy only transfers between the 2 prongs, it only destroys the tissue it is in direct contact with. This makes bipolar instruments ideal for controlling bleeding in the tissue between its 2 prongs. Advanced bipolar instruments are built with an added cutting mechanism that cuts the tissue between the prongs, allowing for dissection after the tissue has been destroyed. Because electrical current travels down the instrument, any exposed metal can again create an injury. Examples of the advanced bipolar instruments are the LigaSure (Medtronic), the Gyrus(PK Gyrus), and the ENSEAL (Ethicon Endo-Surgery). Sometimes these instruments are referred to as vessel sealers.

Ultrasonic energy

In these instruments, heat is generated by the vibration of the instrument itself and this heat is what cuts through tissue and controls vessels. The main advantages of ultrasonic instruments

are that they cut through tissue faster and are good at bleeding control. However, their mechanism reaches temperatures well greater than 200° C and can take up to 30 seconds to return to a temperature that does not cause tissue destruction (<50° C).[160] These instruments should not be used to hold the bowel or other critical tissue after they have been just activated because injury may occur. Some examples of ultrasonic devices are the Harmonic Ace (Ethicon Endo-Surgery) and the Harmonic and Sonicision™ (Medtronic).

Types of injuries

Energy is intended to travel from the electrosurgical unit to the tip of the instrument. Any time there is a conductor that can transmit the energy, energy may be released to the tissue. This can happen in 6 different ways: direct application, insulation failure, direct coupling, capacitance coupling, antennae coupling, and residual heat.[160]

Direct Application. Direct application injuries occur when the energy from an activated device spreads beyond the intended tissue. For example, the surgeon wants to use the laparoscopic hook on a small vessel near the bowel wall. The activated tip touching the vessel may affect tissues beyond the intended vessel and cause tissue destruction in the bowel wall. This can appear as blanching of the bowel wall. Unfortunately, this acts like a burn and the tissue may slough off over time, resulting in a bowel perforation that manifests days after the injury occurs. This can be prevented by limiting the activation time of the instrument and avoiding energy use near hollow viscus organs. Clips can be placed to control small vessels in place of thermal control. If there is suspicion of thermal injury, it is best to place Lembert sutures to cover the injured area with healthy tissue. If the thermal injury is severe enough, resection of the injured tissue may be required.

Insulation Failure. Insulation failure injuries occur when there is a breakdown in the insulation of the laparoscopic instrument. This has been reported in up to 39% of laparoscopic instruments and it can be invisible to the naked eye.[237] Many hospitals now employ porosity testing for their instruments to prevent stray electrical energy from discharging through a break in the insulation. This should be mandatory for hospitals that use laparoscopic techniques. Injuries from insulation failure would be very difficult to identify during the operation because the entire instrument often is not in view.

Direct Coupling. Direct coupling injuries occur when an activated instrument touches another instrument and transfers electrical energy to the second instrument. In open surgery, this technique is often used to control vessels. The surgeon will grasp the vessel with a DeBakey forceps and activate the Bovie to send electricity down the forceps directly to the tissue. The surgeon's latex gloves will protect the surgeon from receiving the energy. If there is a hole in the gloves, the surgeon may experience the transfer of energy and it can result in skin burn. In laparoscopic procedures, if a monopolar instrument such as the endoshears or L-hook touches the uninsulated part of another instrument, then energy will be transferred to that instrument and anything it is touching or holding will have a transfer of energy and an electrical injury. For instance, the activated L-hook may touch the suction irrigator that may be touching a piece of bowel along its shaft, causing an injury to the bowel.

To avoid this type of injury, the surgeon should be judicious when activating the monopolar device making sure it is only touching its intended target. Ports should be placed far enough away from each other so that instruments do not cross over each other. This can be impossible with single-incision laparoscopic surgery techniques.[238] Additionally, ports should not be placed in the flanks such that they are in contact with bowel.

Capacitance coupling. Capacitance coupling occurs when energy builds up within an insulated instrument such that it can transfer energy to other conductive material without it actually touching the other object. This can transfer energy directly to tissue or to another instrument (such as a metal suctioning device or a metal trocar that is touching tissue), which would subsequently injure any tissue it is in contact with. This mainly occurs when high amounts of energy are used with a monopolar device, like prolonged use of the L-hook at 60W to control bleeding in the liver bed after a difficult cholecystectomy.

Surgeons should try to avoid prolonged use at high energy levels to minimize the risk of a capacitance coupling injury. Other energy devices or other methods of controlling bleeding (eg, clips, hemostatic agents, pressure, advanced bipolar, or ultrasonic devices) should be considered in place of increasing the monopolar energy. Additionally, metal trocars should be avoided. In robot-assisted surgery where metal trocars are commonly used, the surgeon should make sure the metal trocars are placed so that they are not too close to other tissue.

Antennae coupling**.** Antennae coupling occurs when the wires of an activated instrument transfer energy to a wire in parallel, causing energy transfer to that instrument. This may happen when the monopolar cord runs parallel to the camera cord for a longer distance, such that the activated Bovie cord transfers energy to the camera cord, allowing it to travel along the camera and into the body. If the camera is touching tissue, then the tissue will get injured. To prevent this, surgeons should not run the camera cord and the Bovie cord in parallel and the camera tower should be on the opposite side of the patient from the electrical generator.

Residual heat. In this situation, the device is not active, but recent use has generated heat in the instrument and anything the instrument touches will subsequently suffer a tissue injury. Monopoloar, bipoloar, and advanced bipolar devices tend to cool down to less than 50° C within a few seconds, so advanced bipolar devices can be used to dissect or hold tissue. The ultrasonic devices, however, reach temperatures higher than 200° C and take up to 30 seconds to cool down to a temperature less than 50° C. Therefore, ultrasonic devices should not be used as dissectors or tissue retractors.

In general, surgeons should know well the equipment they are working with, specifically including the advantages and disadvantages. Inevitably, new devices will enter the market. Robot-assisted surgery companies include advanced bipolar devices in their armamentarium and some companies have energy devices that can perform both in the advanced bipolar fashion and in the ultrasonic fashion (ie, Olympus Thunderbeat). Knowing how the devices work can reduce injury from electrosurgical instruments and also make the surgeon more efficient when operating. This is more imperative with laparoscopic surgery because injuries can occur outside of the field of view (eg, capacitance coupling and insulation failure), long after the instrument has been deactivated (eg, ultrasonic devices), and outside of the patient (eg, antenna coupling).

Immunofluorescence

The use of immunofluorescence can hardly be considered an essential skill for laparoscopy, but it looks like it will become more ubiquitous in the future. It is easy to use and there are no known negative effects from it. In the surgical fields of acute care surgery where anatomy is distorted and tissue is inflamed, identifying critical structures without having to do more dissection can be extremely helpful.

Immunofluorescence can be utilized to help surgeons identify vessels, biliary anatomy, and ureter anatomy; and it can also be used to evaluate for adequate perfusion. ICG dye attaches to plasma proteins and therefore travels wherever blood travels.[232,233] It can therefore detect when blood flow is poor, such as at the ends of an anastomosis. Visualization of the green dye requires near infrared (NIR) light, which is available on several commercially available laparoscopic cameras, including Stryker and Olympus. In cases of mesenteric ischemia, ICG may be helpful in determining which parts of the bowel have inadequate blood flow and identification of areas in need of resection. This can be particularly helpful for patients with a large amount of adipose tissue or inflammation. There are reports of immunofluorescence used to help determine the extent of ischemia in patients with mesenteric ischemia[93,98] (Fig 11). This was performed in both open and laparoscopic cases, but these are retrospective reviews and there were no comparison groups. Although the authors note that there are clinical decisions made as a result of the immunofluorescence, they do not conclude that the use of ICG dye makes a difference. It is reasonable, however, to consider its use for patients where mesenteric ischemia needs to be ruled out. ICG dye reaches the arterial system within seconds after it is administered IV. The recommended dosing is 1-1.5 cc of a solution of 2 mg of ICG in 1 cc of saline.

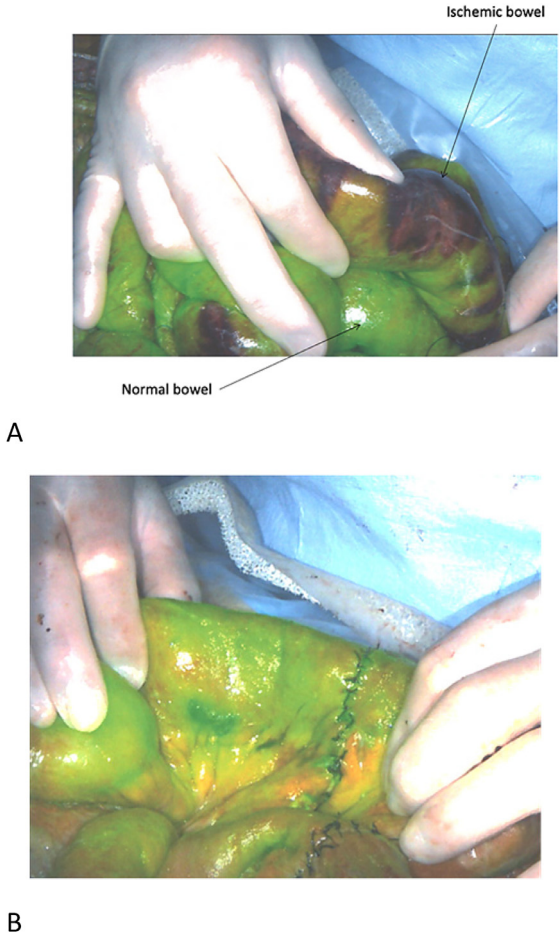


Fig. 11. (A) Appearance of ICG immunofluorescence in ischemic bowel. (B) Appearance of perfused anastomosis with ICG. ICG, Indocyanine green.. Color version of figure is available online

ICG can also be used to identify the extrahepatic bile ducts[239] (Fig 12). Although it cannot help discern if there are CBD stones, it can help locate the CBD even when there is a significant amount of inflammation. As such, it can help the surgeon avoid dissection close to the CBD, which in theory would prevent injury to the CBD. It takes at least 30 minutes for the ICG dye to reach the biliary tree system, so it should be administered prior to the start of the case or as soon as the case starts. There are no data that suggest the ICG use prevents bile duct injuries. The recommended dose is 0.5 to 0.75 mg of ICG administered IV.

The ICG dye can also be used to identify the ureters.[234] This can be helpful in obese patients or in patients with extensive inflammation around the ureter, as with sigmoid diverticulitis. In this application, the dye must be injected via a ureteral catheter, so it requires placement of a ureteral catheter either preoperatively or intraoperatively. This may not always be feasible in the emergency or acute situations. Again, the use of immunofluorescence has not been shown to improve outcomes in this patient population.[234,240]

There is a growing body of literature around the use of ICG dye, and the authors anticipate a better understanding of its benefits in the coming years.

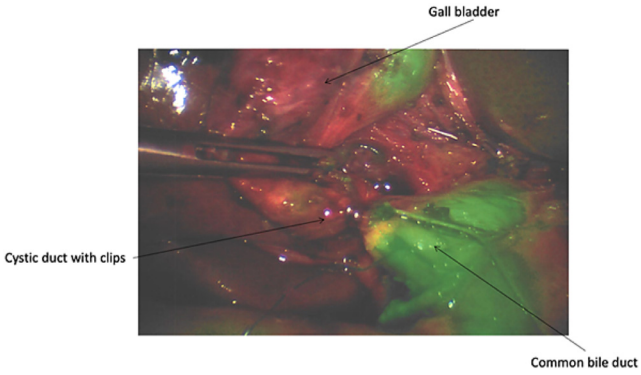


Fig. 12. Immunofluorescence appearance of the biliary tree with ICG during laparoscopic cholecystectomy. The cystic duct has been occluded by clips. Note the tenting over of the common bile duct which demonstrates how easily it can be injured during dissection. ICG, Indocyanine green .. Color version of figure is available online.

Table 18
Complexities of measuring quality for emergency general surgery (EGS) patients versus elective surgery patients.

EGS patients	Elective patients
Non-elective admissions through the emergency department	Outpatient or planned admissions
Minimal or no preoperative optimization	Increasing use of preoperative optimization
Higher incidence of comorbid conditions	Preoperative screening and risk assessment
Surgery performed 24 h a day	Surgery performed during scheduled block time
Not all require surgery	Surgery defines the admission
Timing of surgery variable during admission	Surgery usually performed on day of admission
Service for EGS	Service for Elective Patients
May be admitted to surgical or non-surgical service	Admitted to a surgical service
Can be cared for by a "team" of surgeons in a group practice model	Usually one surgeon is the "primary" surgeon for the patient

Modified from: Staudenmayer K. [248] EGS: Using Registries to Improve Care for a Challenging Population. ACS Quality and Safety Conference. 2019. Washington, DC.

Assessing quality and determining essential surgical skills

EGSQIP – Emergency general surgery quality improvement project

Effective quality improvement requires access to accurate and relevant data to assess structure, process, and, ultimately, outcomes of patient care. Quality registries, such as ACS-NSQIP and the Trauma Quality Improvement Program (TQIP) have set the precedent for quality reporting in surgery.[241,242] Implementation and utilization of NSQIP have been associated with improved outcomes and decreased costs.[243–245] Interestingly, a recent review identified that it is the combination of NSQIP participation with a robust quality improvement (QI) infrastructure and site leadership that has the greatest impact.[243]

EGS has overlap with both programs, but also unique challenges that necessitates the creation of a quality registry focused on this patient population. NSQIP tracks only operative cases, yet more than two thirds of EGS diagnoses are managed nonoperatively.[5,246] Although NSQIP sampling varies by individual site, the majority of the cases are elective and may be even more so in hospitals that target high-end complex procedures which are less commonly performed non-electively (eg, esophagectomy, pancreatectomy, etc.). NSQIP includes many important variables including patient demographics, comorbidities, and laboratory values, but traditionally lacks process measure evaluation. Additionally, EGS has many complexities that impact outcomes that are less frequently present in the elective patient population (Table 18). Finally, EGS carries higher rates of morbidity and mortality based on retrospective database analysis,[247] suggesting that this patient population should be evaluated separately from patients undergoing elective operations.

Table 19
Ideal measures for an Emergency General Surgery Quality Improvement Program (EGSQIP).

Domain	Metric
Structure	Hospital resources
	EGS call coverage structure
Process	Timeliness of evaluation and interventions
	Use of evidence-based guidelines
	Appropriate use of blood and antibiotics
	Post-discharge follow-up
	Long-term care
Outcomes	Morbidity
	Mortality
	Length of stay
	Readmissions
	Cost
	Functional outcomes
	Quality of life
	Return to work or school
	Pain relief

Modified from Shafi S. Pursuing Quality - Emergency General Surgery Quality
Improvement Program (EQIP). *MDedge* 2015.
EGS, emergency general surgery

Variation in outcomes after EGS procedures has also been shown both within and between hospitals.[249,250] Additionally, the risk stratification available through the national NSQIP database is more accurate for elective cases.[251] A pilot was created in 2015 using the NSQIP platform to capture both operative and nonoperative management of EGS diagnoses, specifically appendicitis, cholecystitis, and SBO.[252] Hospital ranking by adverse outcome was substantially changed by the addition of outcomes after nonoperative management, thus identifying a gap in performance evaluation for EGS patients when only operative management is measured.

The ideal registry, EGSQIP, would contain all the necessary data points to successfully identify opportunities for quality improvement and performance improvement. Suggested data points would cross the 3 Donabedian domains of structure, process, and outcomes.[253] Suggested metrics are outlined in Table 19.[254]

In addition to understanding the quality components, it is important to be able to appropriately risk stratify patients. Patient factors include age, gender, race, frailty, and comorbidities. Severity of disease has historically been difficult to measure. The AAST created 5 grades to assess severity[255,256] which have performed well in analysis of association of severity with outcomes.[257–260] In a comparison of AAST Grades and ICD-10 codes, there is not direct correlation.[261] It is not yet known the predictive ability of AAST grades vs ICD-10 codes, especially as the codes were updated in October, 2018 with increased disease specificity (Table 20). Other physiology scoring systems, such as the Sequential Organ Failure Assessment (SOFA), may provide additional information or complimentary disease severity grading with ICD-10 codes.[262] Among current risk stratification tools for operative EGS, a recent review recommended the Emergency Surgery Acuity Score (ESAS) and the ACS-NSQIP Universal Surgical Risk calculator for EGS.[263]

As always, with new endeavors there are unique challenges. The EGS patient population has substantial heterogeneity in almost every patient and disease characteristic. Determining which data elements to prioritize for the sake of efficiency while still meeting the needs for optimal quality improvement will require input from multiple stakeholders. Additionally, the initial task for identifying an EGS patient can be challenging and can vary by setting. For patients with a SBO, should they only be included if that is their presenting symptom or should they also be included if they get a postoperative SBO after an elective procedure? Patients may get identified by their admitting service in hospitals with dedicated EGS service, but there are likely local

Table 20
ICD-10 codes, updated in 2018 with increased disease specificity, shown here for the example of appendicitis.

AAST Grade	Description	ICD-10-CM Code	Description	ICD-10-CM Code	Description
		Prior to October 1, 2018		After October 1, 2018	
I	Acute inflamed appendix, intact	K35.80	Unspecified acute appendicitis	K35.80	Unspecified acute appendicitis
		K35.89	Other acute appendicitis	K35.890	Other acute appendicitis without perforation or gangrene
				K35.30	Acute appendicitis with localized peritonitis, without perforation or gangrene
II	Gangrenous appendix, intact			K35.891	Other acute appendicitis without perforation, with gangrene
				K35.31	Acute appendicitis with localized peritonitis and gangrene, without perforation
III	Perforated appendix with local contamination	K35.3	Acute appendicitis with localized peritonitis	K35.32	Acute appendicitis with perforation and localized peritonitis, without abscess
IV	Perforated appendix with periappendiceal phlegmon or abscess			K35.33	Acute appendicitis with perforation and localized peritonitis, with abscess
V	Perforated appendix with generalized peritonitis	K35.2	Acute Appendicitis with generalized peritonitis	K35.20	Acute appendicitis with generalized peritonitis, without abscess
				K35.21	Acute appendicitis with generalized peritonitis, with abscess

New codes effective October, 2018
AAST, American Association for the Surgery of Trauma.

variations in which disease processes are admitted to which services. In hospitals with general surgeons sharing the EGS call without a dedicated service, patients will need to be identified in other ways.

Although there is a paucity of literature and agreed-upon best practices for an EGS registry, some examples do exist. Surgeons at Walter Reed National Military Medical Center created an EGS registry mirrored after their trauma registry and included patients who required an inpatient consult and follow-up by their EGS team.[264] The United Kingdom has created a registry for patients undergoing exploratory laparotomy, the National Emergency Laparotomy Audit (http://www.nela.org.uk/reports). A recent study in the Michigan Surgical Quality Collaborative identified decreased EGS mortality in hospitals with acute care surgery services, primarily in the intestinal resection cohort.[265] At the same time, not all hospitals have enough general surgeons to run an acute care service.

At the end of the day, success in creating and successfully utilizing an EGS quality improvement data registry will depend on leadership, commitment to quality data, and the resources needed to obtain those data, and the support of stakeholders—at both a national and local level.[266] Identifying metrics for quality EGS care across the spectrum of diagnoses, disease severity, and patient comorbidities will be an important step in the management of this high-risk population, as it is not feasible for every hospital to know how to or have the resources to successfully treat the entire breadth of EGS patients.

Summary

MIS has several advantages to caring for the acute care patient in both EGS cases and in trauma ones. With the exception of the hemodynamically unstable trauma patient, the rare patient in which it is impossible to establish a pneumoperitoneum, and the uncommon patient who cannot tolerate the pneumoperitoneum, most acute care surgery patients are able to undergo laparoscopy or endoscopy. The decision to use these techniques then comes down to the resources available and the surgeon's comfort level. Certainly, the use of laparoscopy does not worsen outcomes. At the same time, there are many examples where MIS techniques are superior to the open approach, and thus, astute acute care surgeons should be incorporating laparoscopic skills like intracorporeal knot tying and therapeutic endoscopy in their skillsets. Even with such skills, though, the decision to persist laparoscopically in difficult cases is not always clear. The benefits of an MIS approach may be overcome by a 6-hour operation that makes extubation difficult and prolongs the length of hospital stay.

Because the risk and the complication rates in acute care patients are so high, acute care surgeons should be looking for ways to improve the outcomes. These improvements would include not only surgical skills and knowledge but also a robust review of all of the acute care patients, even the ones who do not undergo surgery. This takes a commitment from the surgeon, the surgical service, and the hospital. Newer technologies like immunofluorescence, single incision laparoscopic surgery, and robot-assisted laparoscopic surgery may help improve outcomes, but data are not yet available that suggest this is true. Ultimately, the use of MIS techniques in acute care diseases is undergoing progression to the betterment of its patients. As seen in several other specialties, quality improvement projects with 100% review and analysis of outcomes will likely lead to better outcomes and higher quality care, which is desperately needed in a specialty like acute care that is high-risk for complications.

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