Preoperative Optimization for Abdominal Wall Reconstruction

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KEYWORDS

• Abdominal wall reconstruction • Prehabilitation • Ventral hernia
• Preoperative pneumoperitoneum • Botulinum toxin A

KEY POINTS

- The outcomes of abdominal wall rehabiliation may be improved with prehabiliation of comorbidities and prehabilitation of the abdominal wall.
- Advanced age, smoking, diabetes, obesity, cirrhosis, and frailty have been identified as risk factors in the population who may benefit from prehabilitation.
- Emerging data from prehabilitaion programs demonstrates mixed outcomes.
- Prehabilitation of the abdominal wall includes mainly usage of botulinum toxin A for chemical component separation, and preoperative progressive pneumoperitoneum, both effective an appropriately selected population.

INTRODUCTION

Despite regional variation, and referral patterns, the prevalence of complex abdominal wall defects and the need for abdominal wall reconstruction continues to increase. The proportion of these patients having serious comorbidities also seems to be increasing. A systematic review and meta-analysis of 22 studies including 5284 patients who underwent open transversus abdominus release (TAR) identified age, gender, body mass index (BMI), comorbidities, and tobacco exposure as being associated with surgical site occurrence (SSO) and with overall complications.[1]

Because of the risk and costs of postoperative complications, especially surgical site infections, some have suggested that preoperative optimization might be more important than operative technique,[2] though in reality it is a combination of the two which likely to provide the best outcomes.

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In discussing prehabilitation, we can divide the topic into 2 main sections.

1. Prehabilitation of comorbidities—minimizing preexisting conditions that are associated with increased risks of postoperative complication (both early and late).
2. Prehabilitation of the abdominal wall—preoperative adjuncts that allow restoration of midline and/or allow for the procedure to be completed successfully.

PREHABILITATION OF COMORBIDITIES

Age

With an average life expectancy extending into the mid-80s in many developed nations in the world, patients are being referred for surgical consultation with symptomatic hernias later in life. The perceived risks of surgery stem from both the aging organ systems and from multimorbidity (Charlson Comorbidity Index $\geq$3, cognitive dysfunction, and frailty). In a pilot study of patients over age 60 years referred for inguinal or ventral hernia to a tertiary care center, high rates of cognitive impairment (29%–47%), frailty (16%) or prefrailty (53%), and multimorbidity (>94%) were present. Surprisingly, there were no significant differences between the age groups of 60 to 64, 65 to 70, or over 70 years. These findings not only suggest that age is just a number, but also that patients not routinely considered elderly may have some significant associated factors that could affect their outcome.[3] Multimorbidity was also seen more commonly in the older population, 55% to 98% of adults over age 65 years, compared with 30% in younger adults. Multimorbidity in ventral hernia patients is associated with increased length of stay, higher mortality, higher rates of emergency surgery, and higher rates of discharge to a care facility. Higher rates of functional dependence can be noted in older patients, and this is also associated with higher rates of complications and mortality. Further data from the pilot study noted that in the 26 patients who did eventually undergo ventral hernia repair, there were similar outcomes when examining readmission, complications, length of stay, and discharge home without any supportive care when stratified into the tertiles of age over 60 years. Of note, the outcomes predicted by age when using risk calculators such as National Surgical Quality Improvement Program (NSQIP) and Charlson Comorbidity Index (CCI) overestimated the expected postoperative complications.[4] It could however be argued that this was a selected population and outcomes in a tertiary care referral center may not be representative of the population undergoing repair elsewhere.

When focusing on the complex abdominal wall population, in a retrospective study examining 300 patients undergoing TAR, no differences were found in readmission at 30 days, in hospital complications, or surgical site infection (SSI) when comparing ages less than 60, 60 to 70, or greater than or equal to 70.[5] These outcomes are also similar to the findings in an NSQIP study including patients from 2005 to 2013 where no differences were found in complications when including patients undergoing both anterior and posterior components separation. Curiously, SSI rate was lower with advancing age.[6] Overall, age could be a proxy for frailty and multimorbidity, but is likely not an independent risk factor for poor outcome. It is most important to note that the above outcomes focus on what is likely a highly selective population who met selection criteria for hernia repair and not the general elderly population with an abdominal wall defect. Prehabilitation for specific associated risk factors can of course be instituted, but these older patients might also benefit from the use of shared decision-making tools. A small randomized study noted improved hernia specific knowledge retention in the experimental arm where the tool was used with high levels of patient satisfaction.[7]

Smoking

Smoking is associated with tissue hypoxia, poor wound healing, and vitamin C deficiency. It is associated with hernia formation and recurrence. Postoperative wound complications are also higher in current smokers[8], and health care costs following inpatient surgical procedures for up to 1 year postoperatively have been shown to be higher in current and former smokers.[9] Current smokers have a higher recurrence rate even with umbilical hernia repair.[10] They have higher rates of respiratory and infectious complications after ventral and incisional hernia repair, and a higher rate of complications, reoperation, readmission, and death.[11]

With higher risk surgical procedures, it is common for requirements to include 4 weeks of preoperative smoking cessation. Randomized evidence notes that smoking cessation 4 weeks preoperatively decreases postoperative complications from 41% to 21%. This group included patients undergoing hernia repair in addition to other procedures, though no subset analysis was performed specifically for hernia patients.[12]

Surgery has been identified as a "teachable moment" to motivate smoking cessation in adults over age 50 years. Even though the highest rates of cessation are associated with those undergoing cardiac or cancer surgery, outpatient procedures are more common and therefore have the largest population impact. Overall, 8% of all "quit events" annually in the United States have been attributed to surgical procedures.[13]

Various methods of smoking cessation have been investigated and almost any type of intervention has been shown to have some efficacy,[14,15] even if started within 2 weeks of surgery. Preoperative advice at the surgical clinic visit to stop smoking prior to hernia surgery has been shown to be effective in almost 20% of individuals, with the rates being improved with a reminder after the clinic visit.[16]

The most effective methods of achieving smoking cessation perioperatively, and maintaining it long term, involve programs that combine pharmacotherapy with counseling sessions.[17] Nicotine replacement is often used, and the possible risks of nicotine replacement therapy are likely outweighed by the benefits,[18] with some evidence that nicotine replacement therapy is not associated with an increased risk of postoperative complications, mortality or readmissions.[19]

Long-term smoking cessation, which may improve long-term hernia recurrence rates, and is a component of whole health, may be associated with timing of preop smoking cessation. In a worldwide cohort of patients undergoing inpatient surgery, almost 40% remained abstinent at 1 year postop. Patients who had quit smoking over 2 weeks before surgery were more likely to be successful long term compared with those who had quit within 2 weeks, or just prior to surgery (day 0 or 1 before surgery).[20]

Diabetes

Perioperative hyperglycemia has been associated with higher rates of postoperative complications and hospital costs in general surgery patients.[21] This has also been noted in patients undergoing complex ventral hernia repair, where perioperative hyperglycemia has been associated with increased length of stay, cost, and higher SSO rates.[22] HbA1C is often used as a marker of assessing hyperglycemia over the 3 months prior and potentially predicting perioperative hyperglycemia. The relationship is complex as perioperative hyperglycemia is associated with a higher rate of readmission following gastrointestinalsurgery, though preop HbA1C does not demonstrate any such correlation. Patients with a higher HbA1c in this study had more

frequent postoperative glucose checks and received more frequent insulin doses which may have led to tighter perioperative blood sugar control.[23]

Despite conflicting data on the predictive value of HbA1C, expert consensus in 2017 recommends avoidance of elective ventral hernia repair with HbA1C of greater than 8, with preoperative intervention when greater than 6.5%.[24] Recently, an ACHQC study that looked at outcomes in 2167 patients with diabetes mellitus undergoing ventral hernia repair found no difference in 30-day complication rate, SSI, or composite recurrence at 24 months comparing groups with a HbA1C cutoff of 8%. There was a slightly higher readmission rate (7% vs. 5%) in the group with an HbA1C of greater than or equal to 8%. Since this was a retrospective study, it is impossible to identify whether the group with HbA1C of greater than or equal to 8% had undergone preoperative optimization from an even higher value.[25]

Although it is clear that perioperative glycemic control is of utmost importance, it is difficult to discern whether historical glycemic control via HbA1C affects outcomes. Most recommendations, however, continue to err on the side of caution, and the cutoff of HbA1C of 8 remains.

Obesity

The global obesity epidemic has led to an increased incisional hernia rate, in addition to hernias of increased complexity. BMI is commonly used to estimate body fat content, and cutoffs of 35 or 40 are frequently used. Long-term recurrence rates have also been noted to be increased, even in umbilical hernia repairs, where a BMI increase by 1 point outside of the normal range has been associated with a 9% increased recurrence rate.[10] In more complex hernias, higher rates of wound complications have been noted after parastomal hernia repair,[26] and higher recurrence rates after lateral hernia repairs.[27] In open ventral hernia repairs, an increase in SSI is noted with increasing BMI, as a continuum without a cut point off at a specific BMI.[28] In another study, BMI in the fourth quartile (mean BMI = 43.29) was associated with a higher rate of complications, and was associated with the largest amount of additional spending per complication compared with other factors such as insulin-dependent diabetes, unhealthy alcohol use, and smoking.[29]

BMI, however, may also not be the best measurement of obesity, and some data suggest that visceral fat volume as calculated from preoperative computed tomography (CT) scans may be more informative. In a population undergoing open abdominal wall reconstruction, visceral fat volume above the mean was associated with higher rates of SSO and hernia recurrence, even when BMI did not demonstrate an association.[30]

These associations become less clear when considering minimally invasive abdominal wall reconstruction. In a cohort of 461 patients undergoing laparoscopic or robotic retromuscular abdominal wall reconstruction, there were no differences observed in length of stay, total costs, postoperative complications, or recurrence at 1 year when BMI of greater than 35 was compared with BMI of less than 35. Subgroup analysis with the BMI cutoff being raised to 40 did not alter these findings.[31] These findings have been duplicated by other groups where no differences in short-term complications have been noted between those who underwent minimally invasive retromuscular repair with a BMI cutoff of below or above 35.[32] Even in a heterogenous mix of IPOM (intraperitoneal onlay mesh), TAPP (transabdominal preperitoneal), and retromuscular repairs, no differences in outcomes from the standpoint of complications or recurrence free interval were noted when comparing patients with class II and class III obesity.[33,34]

Achievement of weight loss in patients with complex hernias can be challenging. Less than half of the patients with a BMI of greater than or equal to 35 who were

referred to a "weight management navigator" with access to both free and paid programs enrolled in any program. Of those who enrolled, less than half followed up in the hernia clinic at 3 months. Those who participated in the program, however, did lose significantly more weight than those who did not participate (6 kg vs. 1.8 kg).[35]

Given the difficulty of achieving weight loss in some patients, there is a concern about increased hernia complexity developing during this observation period. In a group of patients who underwent open ventral hernia repair, and had 2 preoperative CT scans, several interesting outcomes were noted. Hernia defect size and especially hernia volume increased during the time period of observation regardless of any change in weight. Intra-abdominal volume, subcutaneous volume, and hernia volume were significantly affected by a weight change, both in the 5 kg and the 5 to 10 kg ranges, with less impressive impact over 10 kg. The impact of the weight change was also significantly more in male patients compared with female patients.[36] Similarly, in a group of patients with hernia defects greater than 7 cm horizontally, who underwent observation for various reasons (~50% for operating roomdelays, ~50% for comorbidities, smoking, obesity, lack of symptoms), CT scans over a 6 month time period identified a significant increase in fascial defect area and hernia sac volume. Interestingly, there were no significant changes in hernia-related quality of life scores or physical activity score (The International Physical Activity Questionnaires).[37]

Given the known challenges with achieving weight loss through diet and behavior modification, bariatric surgery is often considered as part of the pathway for the appropriately selected patient. Various studies have demonstrated the safety and benefit of performing a staged bariatric surgery followed by ventral hernia repair to achieve long-term success, even in the complex group of patients with obesity and hernias with loss of domain.[38]

Cirrhosis

Ventral hernias have a high prevalence in individuals with cirrhosis when ascites is present (20%–40%), compared with the noncirrhotic population (2%–3%). This is likely to be multifactorial starting with fascial weakening due to sarcopenia and variceal formation, worsened by increased intra-abdominal pressure from accumulation of ascites. With the risks of skin thinning, breakdown and ascites leak with observation, there are potential benefits to early repair. However, the outcomes from hernia repair can be dismal with recurrence rates as high as 70% to 75% with additional risks of infection and ascites leak when the ascites has not been controlled. Based on the above, watchful waiting has been trialed in patients with cirrhosis. The failure rate of watchful waiting may be 20% to 30%, and the outcomes of urgent repair in this population are worse than in the elective situation, both in prospective and retrospective studies.[39–44]

A VASQIP (The Veterans Affairs Surgical Quality Improvement Program) study has demonstrated a low risk of 30 day and 90 day mortality for umbilical and ventral hernias when performed electively (1%–2%), compared with 13% to 15% when performed on an emergent basis. For all abdominal surgeries, factors associated with poor outcome included MELD (Model For End-Stage Liver Disease) of greater than or equal to 10, low serum albumin, encephalopathy, ascites, and medical comorbidities.[45] Even in umbilical hernias, a systematic analysis of 23 studies with 3229 patients noted that cirrhosis conferred an odd ratio of 8.5 for mortality following repair, with emergency repair being associated with a 2.6 odds ratio compared with elective repair.[46]

With this high rate of failure of observation, and suboptimal outcomes from urgent repair, optimization of the patient with cirrhosis and proceeding with elective repair may be the best pathway to follow. Medical management of ascites should be

optimized. In patients where this cannot be achieved, options include paracentesis and Transjugular Intrahepatic Portosystemic Shunt (TIPS). Both have possible associated complications and should be discussed with a multidisciplinary team. If paracentesis is chosen, repeated paracentesis versus placement of a temporary dialysis catheter at the time of surgery can be considered. In a patient with a high MELD (score > 15), thought should be given to whether the patient is a transplant candidate (with hernia repair at time of transplant). If the patient is not a transplant candidate and cannot be optimized via medical management or TIPS, the risk-benefit ratio of high risk surgery versus supportive care should be considered in a patient-centered approach.[39]

Markov modeling suggests that even patients with an MELD-Na score up to 21.3 would benefit from an elective ventral hernia repair.[47] Even in the scenario of refractory ascites, outcomes similar to those in patients without refractory ascites can be achieved.[48]

In our institution, the protocol for these patients includes US-guided paracentesis the day before surgery (with albumin infusion if needed), followed by weekly, or more frequent, outpatient paracentesis based on patient symptomatology. In urgent cases, consideration can be given to leaving a tunneled peritoneal dialysis catheter allowing for continuous drainage and albumin infusion for 7 to 10 days. A trial can then be performed of clamping the catheter to check that the wound is watertight, followed by removal of the catheter. This of course requires an inpatient stay, but is often reasonable as these patients may require a period of inpatient medical management for liver disease stabilization.

Frailty

There is no clearly agreed upon definition, but frailty tends to refer to reduced physiologic function related to age. It renders patients vulnerable to poor outcomes from medical and surgical procedures. Frailty does increase with age, going from 6.5% from age 60 to 69 years up to 65% at age over 90 years.[49] Various tools have been used to identify frailty and vary in complexity. It is interesting to note that "the eyeball test" continues to have a role with initial appearance of frailty being associated with a hazard ratio of 2.14 for mortality in vascular surgery patients.[50]

In a Michigan Surgical Quality Collaborative Hernia Registry Study, using the 5 factor modified frailty index (mF15) scoring system, 4406 patients undergoing ventral hernia repair were studied. Approximately 47% of patients did not have any frailty, with 36% having moderate frailty, and 17% with severe frailty. Those with severe frailty tended to be older, with higher BMI, higher ASA (American Society of Anesthesiology) class, and with larger hernias. When compared with no frailty, severe frailty was associated with higher odds of any complication, serious complication, SSI, and postdischarge adverse events. Any complications and serious complications were also increased in those with severe frailty at smaller (2 cm) and larger (5 cm) hernia sizes. There was also a higher rate of any complication and SSI in the severely frail group when the operation was performed open.[51]

A described method of identifying frailty is by using CT scan identified sarcopenia as a marker. Sarcopenia is a combination of decreased skeletal muscle mass and decreased strength. CT calculations have been described using the area and Hounsfield units of the psoas muscle. Ventral hernia repair in patients with sarcopenia were noted to have a 5 times higher rate of postoperative complications. Of note, age was not an independent risk factor for postoperative complications.[52] Another study examining sarcopenia and ventral hernia outcomes did not identify any difference in outcome related to sarcopenia. There may be multiple explanations for this, ranging

from the methods of calculating sarcopenia to prehabilitation in specialized centers based on other high-risk indicators.[53] As the above studies demonstrate, there is still more research required to identify whether sarcopenia can be consistently used as a proxy for frailty.

As complex as it is to define frailty, identifying which prehabilitation strategies are most effective may be equally challenging. Most studies that have examined prehabilitation focus on patients requiring orthopedics procedures or oncologic resections. Studies that examine a single modality of prehabilitation have focused on nutrition, exercise, or cognitive therapy. Studies that used a multimodality approach often combined some of the above, with some studies also including psychological counseling, and pain management. The outcomes have been heterogeneous with many resulting in no difference between the groups in terms of postoperative outcomes. Some studies have noted lower SSI, decreased overall complication, and decreased length of stay. Many studies seem to lack adequate power.[54] A multicenter RCT is underway to identify whether 3 weeks of a prehabilitation program for individuals over 70 years identified as having frailty or pre-frailty prior to elective general surgery is effective at 1 year follow-up.[55]

Prehabilitation Programs

The individual comorbidities discussed above can be seen in isolation, but are not infrequently seen in combination in an individual patient. An Americas Hernia Society Quality Collaborative (AHSQC) study of open incisional hernia repair using synthetic mesh in a clean field looking at the modifiable comorbidities discussed above (obesity, diabetes, and smoking) demonstrated that patients with any of these were at increased odds of developing a wound complication at 30 days, with the risks increasing with more than 1 comorbidity. More than 1 comorbidity also increased the risks of requiring intervention for a wound complication.[56]

Prehabilitation programs that are not tied to a specific comorbidity have also been described. Though not specifically a prescribed program, increasing levels of preoperative exercise have been associated with a lower postoperative complication rate and lower readmission rate in patients undergoing ventral hernia repair. This finding may be scalable by incorporating increased exercise in preoperative counseling.[57]

Many patients are not referred for preoperative optimization with surgeons identifying barriers including lack of resources, lack of institutional support, and loss of income and referrals.[58] The addition of pay for performance (for prehabilitation referral), surgeon education, and addition of onsite referral facilitators increased the use of prehabilitation prior to hernia repair by 860% in a pilot project.[58]

In patients diverted to the prehabilitation option for smoking, obesity, or frailty screening based on advanced age, a 1 year follow-up was associated with a low rate of emergency surgery (3%), an increase in the number of low-risk patients seen in clinic who went on to hernia surgery, and an increase in RVUs (relative value units) by 58% attributable to hernia operations. In terms of success of prehabilitation, about 9% of patients underwent surgery, and only 1 patient underwent surgery at another facility over the 1 year time period.[59] Another similar study followed patients where the surgeon elected observation based on risk factors—high-risk comorbidities (15.6%), current smoker (18%), HbA1C of greater than 8%, or BMI greater than 33 (68%). Approximately 78% of the patient desired repair, the majority due to pain or functional limitations. At 3 year follow-up, 66% of the patients were reached, with 1/3 of them having visited the emergency department (ED) due to hernia symptoms. Approximately 37% had undergone repair, 75% of which were elective repairs (majority after having reached preoperative requirements such as weight loss). Those who

had undergone surgery had a lower median pain score, and improved general satisfaction and cosmesis scores compared with at the start of the study.[60]

Success of prehabilitation in all settings is not that clear. Follow-up of a trial of patients randomized into prehabilitation for obesity with BMI of 30 to 40 noted that 70% assigned to the prehabilitation group completed the program and lost weight with a lower postoperative complication rate. However, at 2 year follow-up there was no difference in percentage of patients who underwent hernia repair, experienced complications, or were hernia-free. There was a high use of minimally invasive surgery (MIS) procedures, and the included patients were in the lower BMI range of obesity, with small to medium sized hernias. Patients in the prehabilitation group did not maintain their weight loss and this may well signal the need to discuss posthabilitation in addition to prehabilitation in this complex group.[61]

Even within a structured program for patients identified as being high risk, 45% did not undergo surgery over a 4 year retrospective study. The causes included inability to meet goals, decrease in symptoms, other medical concerns, and seeking care in a different institution. Of the 65% who did successfully undergo surgery for complex abdominal wall defects, the complications were similar in frequency with the low-risk patients.[62]

While considering the high rate of patients who do not undergo surgery while enrolled in structured or unstructured programs, we should consider the patient-reported outcomes following hernia surgery. In patients with incisional hernias, 63% in one study reported postoperative symptoms of pain, a protrusion, or discomfort, with the same percentage also noting that their abdominal wall seemed better than preoperative.[63] Further data correlating postoperative patient-reported outcomes with preoperative comorbidities and the need for prehabilitation may help us further refine counseling to patients regarding postoperative expectations.

The risks of delay in care during prehabilitation have been noted to be relatively low across several studies with the need for emergency surgery being reported at 3% to 7%. It is important to note that when patients are advised on prehabilitation goals without referral to a structured program, there is a low rate of patient follow-up in the hernia clinic.[59,61,64,65]

Prehabilitation of the Abdominal Wall

Patients with complex abdominal wall defects may benefit from prehabilitation of the abdominal wall prior to undergoing surgical repair. The definition of a complex abdominal wall defect has been varied and has included the width of the defect being greater than 15 cm on CT scan, multiple recurrences, and loss of domain (LOD). Lateral wall retraction in large incisional hernias adds to the disability associated with hernia disease with loss of a functional abdominal wall. Restoration of the abdominal wall with fascial closure during hernia repair reverses these physiologic changes. Adjuncts used preoperatively to help achieve this have been termed “abdominal wall prehabilitation.”[66]

Botulinum Toxin

Botulinum toxin A (BTA) is an acetylcholine release inhibitor that has found various uses in medicine, and allows for lateral muscle paralysis in abdominal wall reconstruction. Injection of BTA into external oblique, internal oblique, and transversus abdominus is referred to by some as chemical component separation, and may in some cases allow fascial closure without the need for operative components separation, and in very large hernias, allow for fascial closure in combination with a components separation.[67]

Various injection protocols have been reported, using 100 to 500 units of BTA, diluted with saline, injected with US or CT guidance, with 3 to 5 injections per side using spinal or epidural needles.[68,69] Preoperative timing has also been variable with the majority of studies describing injection at 2 to 4 weeks before surgery.[70,71] Some groups use EMG (electromyelogram) in addition to US during injection to potentially improve the accuracy of the injection sites.[72]

It is unclear whether all 3 layers need to be injected, and there is some suggestion that the outcomes are similar from the standpoint of fascial closure, with the advantage of decreased cost due to a smaller amount of BTA used with 2 layer injection.[73] There is also some thought that if a transversus release is being considered, perhaps preoperative BTA injection to that muscle is unnecessary.

The chemical paralysis leads to elongation of the lateral muscles, with estimates of 3.2 cm per side, 6.3 cm total in a meta-analysis of 4 studies. Conversely, transverse hernia width is decreased by 3.5 cm, in a meta-analysis of 3 studies.[74] A systematic review noted median elongation of 4.0 cm per side, with two-third of patients with large hernias not requiring additional components separation to complete the hernia repair.[66] Another meta-analysis of 14 studies identified at 100% defect closure rate with a median hernia recurrence of 0% (0%–9%) at a median follow-up of 19 months.[74]

As we attempt to identify which patients may benefit from preop BTA, it may be helpful to identify preop those who are likely to require components separation at time of surgery. CT-based measurements of hernia dimensions including volume, area, and ratio of hernia to intra-abdominal volume have been shown to help predict the need for component separation.[75] The next step may be to use image-based deep learning models on preoperative CT image findings. This has demonstrated an accuracy of 81% compared with surgeon prediction of 65% at identifying the need for components separation to achieve fascial closure.[76] A simpler calculation is the rectus width to defect ratio (RDR), calculated by adding the right and left rectus widths and dividing by hernia width. RDR greater than 2 is associated with a fascial closure without the need for myofascial release in 90% of patients.[77] One intriguing idea that will require some study is the idea that BTA should be considered in patients at high risk for recurrence as postoperative laxity may decrease tension on the linea alba.[66]

Preoperative Progressive Pneumoperitoneum

Preoperative progressive pneumoperitoneum (PPP) was first described in the 1940s by Goni Moreno. The original description included repeated access into the peritoneal cavity to instill air with the patient being hospitalized throughout the treatment.[78] It has been initially described for an incarcerated epigastric hernia, but has been adapted over the years to assist in cases of loss of domain to facilitate reduction of contents intraoperatively, achieve fascial closure, and avoid postoperative compartment syndrome.

A generally accepted definition of LOD is when the volume of the hernia sac is greater than 25% of the volume of the abdominal cavity. Two volumetric calculations have been described:the Sabbagh method and the Tanaka method, with the former one being selected as the ideal one in a Delphi consensus in 2020.[79] The Sabbagh method requires volumizing software, whereas the Tanaka method uses the formula for an ellipsoid for calculation.[80]

Techniques for achieving progressive pneumoperitoneum include peritoneal dialysis catheters, central venous catheters, Foley catheters, tunneled venous catheter, or needle access on each occasion. Ambient air and nitrous oxide instillation have

been described, with daily injections of 500 to 1000 mL, titrated to symptoms or pressure measurements. Length of time has varied in reports with the majority being in the range of 14 to 30 days. Repeated veress needle access for each session is still used by some groups.[81,82]

Methods of placing temporary catheters to allow for easier access and increased patient tolerance have been described using local anesthesia, or interventional radiology for insertion of the catheter. Using US or CT guidance, a veress or spinal needle is inserted laterally, with creation of pneumoperitoneum, confirmation with radiology, and seldinger technique being used for catheter insertion into a pocket of air.[83]

Various schedules of injections have been described, from as frequently as twice a day to once every 2 to 3 days. The amount insufflated has also varied, from 1 to 2 L to unmeasured quantities based on patient tolerance. Some groups have focused on basing these on the CT measured hernia volume, and instilling the same volume versus up to 3 times the volume, based on patient tolerance.[84,85] When instilling larger quantities, fractionating into 2 equal injections (1 L twice a day) has also been described to allow for improved tolerance while maximizing the effectiveness.[86]

The gas instilled has also varied to include carbon dioxide, oxygen, and ambient air. There are no clear benefits to the use of gases that are more expensive than ambient air, and which are likely also to be more quickly absorbed from the peritoneal cavity. To avoid preferential insufflation of the hernia sac, some recommend the use of an abdominal binder.

The use of PPP is usually in the elective situation, though it has been described in the "semi elective/semi urgent" scenario where a patient presents with an incarcerated hernia, which is urgently reduced, and PPP is undertaken over the following 2 weeks followed by hernia repair.[87]

Postulated benefits of PPP include increasing the abdominal compartment volume, pneumatic adhesiolysis, improving diaphragmatic function, and reducing chronic edema of the mesentery.[88] Venous thromboembolic prophylaxis is almost universally recommended during the PPP administration.[82,83]

Complications related to PPP are common with reported rates of 17% to 60%. Many of these are mild, with nausea, shoulder pain, dyspnea, and pain at the puncture site almost being expected routinely.[86] With the use of imaging, pneumothorax, pneumomediastinum, and subcutaneous emphysema have been noted. Many are reported as incidental findings, which have resolved with deflation of the pneumoperitoneum. Serious complications have also been reported during catheter insertion, including intra-abdominal hematoma and small bowel perforation.[72,82] Rare complications during the administration of PPP following catheter placement include small bowel perforation,[89] and formation of a peritoneocutaneous fistula.[90]

BOTOX AND PREOPERATIVE PROGRESSIVE PNEUMOPERITONEUM

As the benefits of preoperative BTA in complex abdominal wall repair were being realized in achieving fascial closure, the addition of PPP to this technique has been studied more recently. Most of the described techniques involve the administration of BTA 4 to 6 weeks preoperatively, to increase the compliance of the lateral muscles, followed by PPP for a shorter period of time starting at 2 weeks preoperatively. Studies where serial CT scans have been performed demonstrate that there is an additive effect of the 2 modalities. BTA has demonstrated a gain of 3.2 cm per side, with 4.4 cm following PPP.[82] Fascial closure rates of up to 97% have been reported with the combination of PPP and BTA. The benefits of BTA are purported to be with muscular relaxation and PPP with improvement of the hernia to abdominal cavity volume ratio.[72,74,91]

The combination of the 2 techniques has also been shown to have a lower SSO rate in a small study-potentially due to decreased tension on the midline closure with the addition of BTA compared with single modality PPP.[81] The expected lengthening of muscles and decreasing hernia width have however not been consistently noted in the published data,[74] potentially since the increased intra-abdominal pressure from PPP might be counteracting the relaxation from PPP on preoperative imaging. Vigilance should remain high to identify and treat the rare case of postoperative abdominal compartment syndrome.[72]

INDICATIONS FOR BOTULINUM TOXIN A AND/OR PREOPERATIVE PROGRESSIVE PNEUMOPERITONEUM

There are varying recommendations for use of the adjuncts described above. For the use of BTA, some recommendations include scenarios such including a hernia width greater than 10 cm, recurrence after component separation, loss of domain greater than 20%, retracted bulky lateral muscles, and expected difficulty in closing the midline.[67,92] There is some overlap in the indication for PPP with loss of domain over 20% to 25%, hernia width greater than 10 cm, and inability to reduce hernia contents.[92]

The lack of randomized studies and the heterogeneity in the published data make it difficult to make clear recommendations. At a minimum, we can state that BTA seems to be associated with low risk of complications, whereas PPP should only be considered where expertise is available, and appropriate surveillance should be maintained to identify complications early.

SUMMARY

Patients requiring abdominal wall reconstruction often benefit from evaluation of comorbid conditions to attempt preoperative optimization and/or evaluation of the hernia characteristics to consider BTA/PPP. The data regarding prehabilitation for comorbidities are variable, but promising, whereas the data regarding prehabilitation of the abdominal wall are quite consistently supportive of the use of these adjuncts. These complexities are seen in the dichotomy of the systematic analysis of systematic analyses concluding that there is low certainty of possible improvement in outcomes with prehabilitation.[93] However, a Delphi consensus statement identified several statements with over 80% agreement regarding perioperative optimization of the patient with a ventral hernia. These included recommending weight loss via medical management or weight loss surgery when BMI greater than 35, smoking cessation, blood sugar management in diabetics, exercise prehabilitation for those with poor exercise tolerance, treatment of malnutrition, and access to BTA for use when appropriate.[94]

DISCLOSURES

The author does not have any disclosures relevant to the subject matter of this article.

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