Evidence-Based Strategies for the Prehabilitation of the Abdominal Wall Reconstruction Patient

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Summary: It is inherently challenging to achieve successful surgical outcomes for ventral hernia repairs. For complex ventral hernias, attempts to reconstruct the abdomen in patients who are overweight, deconditioned, malnourished, chronically infected or inflamed, have previous hernia recurrence, or otherwise carry a number of serious comorbidities affecting their surgical fitness are a major undertaking requiring careful preparation and planning. As the rate of abdominal wall reconstructions rises, so does the complexity of these procedures. One could argue that the prehabilitation of these patients is equally, if not more, important than the surgical technique itself. To achieve desirable outcomes and avoid surgical-site occurrences (SSOs), the surgeon must familiarize him/herself with ways to optimize a patient preoperatively. Understanding and identifying the aforementioned modifiable risk factors for SSOs is crucial. It is also important to recognize the impact that acute changes in the microbiome perioperatively can have on the postoperative success. Familiarizing oneself with the available literature for these patients is imperative. This review presents discussion and guidance for understanding the challenges and best practices for providing hernia surgery and abdominal wall reconstruction and achieving durable outcomes, with minimal SSOs. (*Plast. Reconstr. Surg.* 142: 21S, 2018.)

It is inherently challenging to achieve successful surgical outcomes for ventral hernia repairs (VHRs). For complex ventral hernias, attempts to reconstruct the abdomen in patients who are overweight, deconditioned, malnourished, chronically infected or inflamed, have previous hernia recurrence, or otherwise carry a number of serious comorbidities affecting their surgical fitness are a major undertaking requiring careful preparation and planning. This review presents discussion and guidance for understanding the challenges and best practices for providing hernia surgery and abdominal wall reconstruction (AWR) and achieving durable outcomes, with minimal surgical-site occurrences (SSOs).

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EPIDEMIOLOGY AND FINANCIAL BURDEN

Unfortunately, VHRs are increasingly more common; the rate of ventral hernias and AWR has increased, as have the complexity of these cases.[1,2] As AWR becomes more challenging, complication rates have increased. Infection is the most frequent complication in the postoperative period.[3–5] Hernia

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recurrence is the most significant outcome measure in the longer term, often with delayed presentation, with 89% of recurrent hernias presenting out to 5 years.[6] After each subsequent repair, the risk for progressively earlier recurrence increases.[7] The financial burden for hernia surgery is significant, with the care of a small percentage (15%) of the population comprising half of the total spending for hernia surgery.[1] This minority population tends to be older, with more serious comorbid conditions. Plymale et al.[8] (2017) reported that complex hernias and more ill patients are likewise associated with higher hospital and postdischarge costs (eg, readmission, emergency room visits) occurring within the 90-day period. Other costs that are harder to capture include the cost for skilled nursing facilities, long-term acute care, wound care, and outside hospital readmissions. A "vicious cycle" develops, whereby a hernia repair may lead to an intractable cycle of infection, hernia recurrence, reoperation, and readmission (Fig. 1).[9] As government and private payers place increasing emphasis on readmission rates for determining reimbursement, this shift becomes an important factor in performing hernia surgery.[10] Merkow et al.[4] reported a readmission rate for surgical-site infection of 26.5%, in American College of Surgeons NSQIP data,[4] suggesting VHR and AWR may become prohibitively costly to all involved, while, at the same time, ventral hernias become more common, complex, and morbid.

EFFECTS OF MAJOR SURGERY ON METABOLISM

Hernia repair and AWR are major surgical stressors, inducing a predictable sequence of metabolic and physiologic changes in the patient. Discussing these

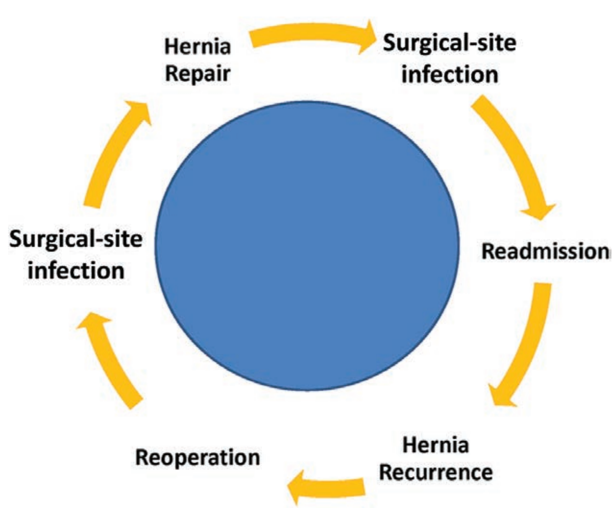

Fig. 1. The vicious hernia cycle.

events highlights areas for intervention and steering the patient toward a more favorable physiologic condition before, during, and after their surgery. First, the inciting surgical insult is detected, and the body initiates rapid changes in the neuroendocrine system, whereby there is increased activity of the sympathetic system and hypothalamic-pituitary axis. This leads the body to tilt toward a catabolic state to provide substrate for mounting a response to the trauma.

The sympathetic response increases available glucose and downregulates insulin production, leading to a relative hyperglycemic state. The hormonal response, mediated via the hypothalamic-pituitary axis, leads to increases in circulating stress hormones including cortisol, glucagon, and growth hormone. This change leads to hyperglycemia and insulin resistance. While the cellular benefit of hyperglycemia may seem favorable for short-term survival, this state is detrimental to surgical recovery and immune function.[11] Increases in circulating cortisol drive catabolic changes, leading to skeletal muscle breakdown, with loss of lean body mass and functional impairment. This proteolysis may be offset somewhat by the patient's preoperative physical condition and age. Fat metabolism plays a significant role, with up regulation of lipolysis to mobilize glycerol and fatty acids for use. More recently, the role of immune-related nutrients has come into focus. Specifically, the amino acids arginine and glutamine are depleted in the postsurgical state, and evidence exists suggesting replacement improves outcomes.[12] The effects on the modulation and attenuation of the inflammatory response to the catabolic effects of surgery by omega 3 fatty acids [eicospentanoic acid (EPA) and docosahexaenoic acid (DHA)] have been well documented. Recent data would also suggest that the EPA and DHA serve as substrate for production of specialized proresolving molecules that are shown to have multiple benefits in accelerating the resolution of inflammation, decreasing pain associated with surgery, and enhancing the function of macrophages in bacterial killing without increasing the inflammatory state.[13,14] For patients who are unable to resume a balanced enteral diet soon after surgery, micronutrient supplementation with vitamins may be needed.

PREOPERATIVE MODIFIABLE RISK FACTORS

The goal of preoperative preparation and optimization is to account for and intervene upon factors known to contribute negatively to AWR outcomes (Table 1). Obesity, smoking, diabetes,

Table 1. Summary of Prehabilitation Recommendations

Obesity
No elective repair if BMI > 50
Dietician consultation
If ineffective, referral to bariatric surgery clinic
Authors' preferred method is separate surgeries (bariatric surgery first, hernia repair second)
Smoking
Cessation for minimum 30 d preoperatively
Nicotine replacement therapy allowed
Diabetes mellitus and hyperglycemia
HbA1c < 7.5% for elective repair (goal of < 6.5%)
Perioperative blood sugar goal 120–160 mg/dL
Early involvement of inpatient glycemic teams when blood sugar is poorly controlled
Carbohydrate loading
300 mL of isotonic beverage (50 mg of complex carbohydrate) 3 hours before surgery (if in accord ance with anesthesia policy)
Sarcopenia
Dietician consultation
Protein intake goal of 1.5–2.5 gm/kg/d
Supervised resistance exercise training
Microbiome
DO give prophylactic antibiotics (ie, first-generation cephalosporin) 30–59 min before incision
DO NOT recommend prophylactic postoperative antibiotics
DO NOT recommend preoperative bowel preparation
Homeopathic medications
Consider cessation for at least 3 weeks preoperatively

malnutrition, and surgical-site contamination are among the most commonly cited.[15]

Obesity

Obesity is a prevalent and significant risk factor for SSO (seroma, dehiscence, fistula, infection) and hernia recurrence. The risk for recurrence has previously been found to increase linearly as BMI increases, irrespective of the type of repair performed.[16–18] This finding, however, has recently been challenged by the work of Giordano et al.[19], who report that increasing BMI was associated with higher SSO rates, but not increased risk of hernia recurrence.

This study considered a BMI less than 40 in an oncologic patient population and used exclusively bioprosthetic mesh, which may somewhat limit the generalizability. These data clearly challenge long held dogma among hernia surgeons concerning risk factors for hernia recurrence and provides a valuable resource for preoperative counseling and planning. We have found that in patients with BMI ≥ 50, the recurrence and SSEO rate is prohibitively high. Therefore, we no longer perform elective herniorrhaphies for these high-risk patients, unless they have stigmata of acutely worsening symptomology (eg, recurrent obstruction, evolving ischemia, strangulation, an so on). Other authors have placed the upper BMI limit at 42.[20,21]

Weight loss counseling centers around describing the rationale vis-à-vis AWR surgery, reviewing specific dietary modifications and exercise plans (within the limitations of patient ability), setting realistic goals (15–30 pound weight loss), and consulting with a dietician. If that is ineffective, surgery is postponed, and the patient is referred to the bariatric surgery clinic for consideration for endoscopic, laparoscopic, or open methods of weight loss surgery. It appears success is variable with conservative measures, and a multidisciplinary team may have better success.

Some debate exists about whether to repair hernias at the time of weight loss surgery. Using American College of Surgeons National Surgical Quality Improvement Program data for all VHRs, Spaniolas et al. described an increased 30-day infection risk with concurrent VHR and weight loss surgery (sleeve gastrectomy or roux-en-Y), but within expected limits for a dual procedure. They advocated for a concurrent approach that would minimize the morbidity of 2 separate procedures without any extra morbidity from the hernia repair. These are short-term data from a large registry, and we believe that AWR outcomes are improved when patients realize the full benefit of weight loss surgery, including metabolic and endocrine changes, weight distribution, cardiopulmonary improvement, and increased mobility, and motivation for pre- and postoperative activity.

Smoking

Detrimental effects of smoking include reduction of both blood and tissue oxygen tension levels and negative effects on the deposition of collagen at the surgical site, leading to increased frequency of complications.[23–25] Smoking broadly increases the risk for complications in gastro-intestinal surgery,[26] specifically VHR.[27–29] VHR and AWR involve several factors that increase risk for impaired healing and infection, including the use of undermined skin flaps, mesh products, reducing chronically incarcerated hernias, or other concurrent gastrointestinal surgery (fistula take down, parastomal hernias, and so on). It is therefore imperative that patients quit smoking for at least 30 days before surgery, as this duration has been shown to be the minimal effective time period for reducing the risk of 30-day complications in a cohort of patients undergoing general surgery and orthopedic procedures.[29] With patient compliance, infection rates quickly approach those of nonsmokers. Interestingly, debate exists regarding the timing and means for cessation. A surgeon may require cessation before VHR, but not allow nicotine replacement therapy, due to concerns about vasoconstriction and impaired healing. Several studies, however, have shown nicotine replacement may be safely used in the preoperative setting without negative effects on surgical outcomes.[23,30] While these data may not necessarily apply to other plastic surgery procedures, it is a useful finding, as patients will anecdotally report that nicotine replacement improves their compliance with their smoking cessation program. For all patients desiring elective complex VHR, we require smoking cessation for a minimum of 30 days preoperatively, and allow nicotine replacement formulations, if desired.

Diabetes and Hyperglycemia

Blood sugar control in the preoperative setting is essential for reducing the risk of infection and other complications in elective surgeries.[31–33] Glycemic control is most commonly measured with a hemoglobin A1C blood test. A common cutoff of 7.5% is used for elective repairs, measured 30–60 days preoperatively, with a goal of 6.5%.[31] Patients with difficulty reaching an HbA1c level below 7.5% may benefit from a more concentrated and focused education plan, provided by a diabetic nurse, their primary care physician, or an endocrinologist. Efforts at weight loss may also help with blood sugar control. Perioperative blood sugar control should target a goal of 120–160 mg/dl to reduce the risk of infection and other complications.[34–37] Postoperative hyperglycemia is a significant risk factor for the development of SSOs following complex VHR, with increased cost, length of stay (LOS), and time to first enteral feeding.[33] In fact, even 1 instance of preoperative or postoperative serum glucose above 200 mg/dl increases the risk of dehiscence significantly.[38] The target glucose range is the same for diabetic and nondiabetic patients. Outcomes may, in fact, be worse for nondiabetic patients who develop hyperglycemia.[26,39,40] Protocols for aggressively intervening upon hyperglycemia have been effective at reducing perioperative hyperglycemia and improving outcomes.[38,39]

Additionally, the use of preoperative carbohydrate loading has been explored as a way to reduce perioperative hyperglycemia and/or insulin resistance. Patients consume 300 ml of a clear isotonic beverage containing 50 mg of a complex carbohydrate 3 hours before surgery to offset the insulin resistance that occurs with a typical NPO regimen for general anesthesia. Though some benefit exists with this regimen in improving insulin resistance, maintaining muscle strength, decreasing patient anxiety, and LOS,[41,42] there is no major change in overall outcome data to date.[43] With this mix of outcome data, the recent European Society for Clinical Nutrition and Metabolism consensus guidelines for surgical nutrition ultimately advocated for the carbohydrate loading program,[44,45] but will require further research to demonstrate its full benefit versus current standards.

Sarcopenia

Sarcopenia refers to a combination of progressive loss of lean body mass with associated functional impairment,[46] and is seen in approximately 27% of the VHR and AWR patient population at our institutions. It is associated with both increasing age and specific disease states, including cancer and liver disease. Sarcopenic obesity is particularly morbid, and is associated with a significant decrease in overall survival compared with sarcopenia alone.[47] Sarcopenia is measured by examining the cross-sectional muscle area (cm^2/m^2) of the paraspinous muscles on computed tomography (CT) imaging at the L3 spinal level.[48] These values are then compared with sex-specific cutoffs to determine whether sarcopenia is present.[46] Sarcopenia is predictive of poor outcomes in numerous surgical and critical care settings.[49–54] In a colorectal patient cohort, sarcopenia was significantly associated with increased postoperative infection, LOS, and need for postoperative inpatient rehabilitation services.[48] For elderly patients sustaining trauma, the presence of sarcopenia predicts increased mortality rates, ventilator dependence, and prolonged critical care needs. Equally impressive is the finding that sarcopenia is associated with worse survival rates in biliary cancer patients.[51] While its role in VHR and AWR is still being investigated, it is clear that a more nuanced measurement (compared with BMI, for instance) for assessing fitness and physiologic capacity, is needed to care for an aging and increasingly obese population requiring hernia surgery. There are, however, encouraging data for interventions to preserve lean body mass in the elderly or critically ill patients who may be extrapolated to complex VHR and AWR patients. Protein intake goals of 1.5–2.5 gm/kg/d, combined with resistance exercises provide the best chance for preserving or regaining muscle mass and functional status following major surgery and rehabilitation.[55–60] Research into the effectiveness of enhanced protein supplementation and resistance exercises for reducing sarcopenia rates and possibly hernia surgery complications is urgently needed, particularly for the elderly population who appear to be most commonly afflicted by this condition and its sequelae.

Assessment of Preoperative Conditioning and Fitness Enhancement Programs

Surgeons have largely accepted that poor patient fitness portends poor outcomes. The development of surgical risk calculators has taken that a step further to use biometric variables and laboratory data to calculate objective 30-day perioperative risk estimates.[61] Functional status can be quantified and is strongly predictive of postoperative outcomes. Reddy et al.[62] found that a prolonged timed stair climb was the strongest predictor of complications following abdominal surgery. This stress likely simulates the physiologic demands of surgery and can help identify patients who may benefit from further conditioning before surgery. This has given rise to an interest in preconditioning, or prehabilitation to improve upon functional status. Using a combination of psychological, physical, and nutritional interventions, prehabilitation aims to improve the overall condition of the patient before surgery. It appears to be effective for improving functional capacity in colorectal patients[63] and reducing complications in elective abdominal aortic aneurysm repair surgery.[64] Given the heterogeneity of the surgical disease being treated and the program itself, there has not been large-scale evidence that supports its use.[65] With these and other encouraging data,[66–68] however, therapies will no doubt be investigated for the VHR and AWR population.

NUTRITIONAL ASSESSMENT

Poor nutritional status has long been associated with higher rates of postoperative complications and adverse outcomes for patients undergoing elective surgery. Despite the importance of nutrition, the emphasis on preoperative nutritional optimization is lacking. Identifying and optimizing undernourished patients preoperatively has potential to significantly improve patient outcomes. Multiple prospective randomized control trials have shown that preoperative nutritional optimization decreases complications, LOS, and rehospitalization.[69–71]

Several relatively simple screening tools exist to identify patients who would benefit from nutritional intervention. Nutritional Risk Screening 2002 is a system for screening nutritional risk. There are 2 parts **(see Appendix, Supplemental Digital Content 1**, which shows nutritional risk status at initial screening and final screening defined by the present nutritional status and risk of impairment of present status, due to increased requirements caused by stress metabolism of the clinical condition, ***http://links.lww.com/PRS/C930***). If the patient has a BMI < 20.5, unintentional weight loss within the past 3 months, reduced dietary intake in the past week, or severe illness, then the second part of the screening is performed. There, the patient's impaired nutritional status and severity of disease are scored. If the patient is 70 years old or older, an additional point is added. If the total score is ≥ 3, a nutritional care plan is initiated. The Nutritional Risk Screening has been validated in surgical patients.

Nutrition Risk in Critically Ill score is another commonly used tool to estimate nutritional state.[72] It is validated in the intensive care unit (ICU) population for both medical and surgical patients. It is calculated by assigning a score of 0–3 for 6 variables: age, acute physiology, and acute chronic health evaluation II score, initial sequential organ failure assessment score, number of comorbidities, and days in hospital to ICU admission (Table 2). Patients with a score of > 6 are considered to be at high risk of malnutrition and may benefit from intervention.

The nutritional evaluation of a patient is far more complex than utilizing a single laboratory marker. Visceral proteins, such as albumin and prealbumin were historically used as markers of nutritional status. These markers, however, are neither sensitive nor specific for detecting malnutrition. In particular, in an inflammatory state (either acute or chronic), the production of these visceral proteins is decreased in favor of synthesizing acute phase proteins such as C-reactive protein (CRP). Thus, the relevance of visceral proteins as indicators of nutritional status is limited. Several studies have shown they do not correlate well with a patient's true nutritional state. If visceral proteins, such as albumin and prealbumin are used, they should be used only as a surrogate for potential nutritional compromise or for indication of inflammatory state. The ratio of prealbumin to CRP has been useful, with prealbumin going up as CRP as a marker of inflammation coming down.

Body Compositional Analysis

Body composition refers to the compartmentalizing of the body into the amount of fat mass, lean mass, as well as bone mass or skeleton. This can be evaluated by several methods, including

Table 2. Nutrition Risk in Critically Ill Scoring System

Variables	Points 0	1	2	3
Age (y)	< 50	50–75	> 75	—
APACHE II	< 15	15–20	20–28	> 28
SOFA	< 6	6–10	> 10	—
No. of comorbidities	0–1	2+	—	—
Days from hospital to ICU admit	0–1	1+	—	—
IL-6	0–400	400+	—	—

APACHE II, Acute Physiology and Chronic Health Evaluation; IL, interleukin; SOFA, Sequential Organ Failure Assessment.

bioelectrical impedance analysis, CT, ultrasound, and magnetic resonance imaging, each with pros and cons. These methods have all been used to evaluate nutritional status in the surgical patient.[47,73–75] CT, using cross-sectional evaluation of muscle to adipose ratio at lumbar vertebrae 3, has recently been proven an excellent and validated predictor of outcome in most cancers examined to date.[76,77] A simple and fast analysis of a single CT image (especially if a CT was obtained for surgical planning purposes) could be valuable for preoperative risk assessment; more data are needed, however, before making this routine practice.

Nutritional Modulation of Metabolic and Immune Response

Preoperative immune and metabolic modulation has gained fairly widespread acceptance, following a series of publications by Braga et al.[78–80] and Gianotti et al.[81] in the early 2000s. These studies showed that by delivering a formulation of arginine, omega-3 fatty acids, DHA, EPA, and nucleotides for 5 days preoperatively, complications, hospital LOS, and total hospital financial expenditure could be reduced. Although the mechanism is not entirely clear, several clinical studies suggest that arginine supplementation improves protein kinetics, wound healing, T-lymphocyte function, and M1 to M2 macrophage conversion.[12,13,82] Omega-3 fatty acids attenuate metabolic response to stress, decrease inflammation, and showed actual resolution of the inflammatory response sooner in new data.[12,13]

ALTERING OR STABILIZING THE MICROBIOME IN THE PERIOPERATIVE PERIOD

Acute changes in the microbiome have been shown to alter systemic metabolism. Many surgeons make it customary practice for their patients to shower with chlorhexidine gluconate soap the night before and morning of surgery. Seven randomized controlled trials involving a total of 10,157 patients were examined in a 2015 Cochrane Database review of preoperative bathing with skin antiseptics. No clear benefit in reducing surgical-site infections was found for preoperative showering with chlorhexidine over other products.[83] A recent study of prospectively collected data in VHR found that showering the night before with chlorhexidine increases the risk of infection.[84] Acute changes in the normal skin microbiome before surgery may increase infection risk by converting the skin flora to a pathobiome.[85] More data are necessary, however, before making these changes in practice.

The same can be said about altering the GI microbiome. Several studies have shown that the gut plays a key part to the human stress response in critical illnesses.[86–90] When healthy, the barrier function of the GI tract is intact, and the bacteria supports symbiosis and homeostasis. When undergoing major surgery or in critical illness, the barrier function can be disrupted, and the gut becomes more permeable to potentially virulent organisms.

According to guidelines jointly developed by the American Society of Health-System Pharmacists, the Infectious Diseases Society of America, the Surgical Infection Society, and the Society for Healthcare Epidemiology of America, patients undergoing routine VHR should be given prophylactic antibiotics (a first-generation cephalosporin) within the first hour before incision to decrease surgical-site infections.[91] More specifically, administration of antibiotics should occur 30–59 minutes before incision.[83] Retrospective literature exists supporting continued postoperative antibiotic use when surgical drains are used, but no level 1 data confirm this.[92] We must acknowledge that use of antibiotics undoubtedly alters the GI microbiome, and there are adverse consequences of extended antibiotics. Antibiotic-associated diarrhea and *Clostridium difficile* diarrhea are well-documented side effects of prolonged antibiotic use. Further data are necessary to determine the appropriate duration of antibiotics, but it appears from the majority of prospective studies that prophylactic antibiotics should stop when the skin is closed.

Bowel preparation before AWR is still routinely performed in several centers, and few data exist to support this plan. A recent study evaluated the effect of preoperative bowel preparation on surgical-site infection utilizing the Americas Hernia Society Quality Collaborative.[93] Using prospectively collected data from 3,709 patients, logistic regression modeling was performed. They found that those who underwent a preoperative bowel preparation were more likely to develop an SSO, requiring procedural intervention.

Homeopathic Remedies

Some patients undergoing AWR may take homeopathic medications at home, including herbal supplements. They are especially common in patients undergoing plastic surgery.[94] Patients should be specifically asked about these supplements preoperatively, as many of them may cause bleeding, hypertension, sedation, and other untoward perioperative complications.[95] These supplements should be stopped at least 3 weeks before surgery.

CONCLUSIONS

As the rate of AWRs rises, so does the complexity of these procedures. One could argue that the prehabiliation of these patients is as important as, if not more important than, the surgical technique itself. To achieve desirable outcomes and avoid SSOs, the surgeon must familiarize him/herself with ways to optimize a patient preoperatively. Understanding and identifying the aforementioned modifiable risk factors for SSOs is crucial. It is also important to recognize the impact that acute changes in the microbiome perioperatively can have on the postoperative success. Familiarizing oneself with the available literature for these patients is imperative.

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