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ORIGINAL ARTICLE

Consensus in ERAS protocols for ventral hernia repair: evidence-based recommendations from the ACHQC QI Committee

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Abstract

Purpose Enhanced recovery after surgery (ERAS) protocols are widely used in the post-operative care of hernia patients. Despite their prevalence, an absence of published consensus guidelines creates significant heterogeneity in practices. The aim of this study was to evaluate elements in ERAS protocols utilized in ventral hernia repair from institutions across the United States and provide consensus recommendations for each identified element.

Methods Institutional members of the Abdominal Core Health Quality Collaborative (ACHQC) Quality Improvement (QI) committee submitted current ERAS protocols. Items within each protocol were classified as "elements", then assigned a topic. Any topic with ≥ 2 elements from separate institutions were labeled as a "theme," then grouped by stage in the patient care cycle. A brief review of current evidence was provided in addition to a ACHQC QI committee consensus statement.

Results A total of 295 elements from 6 tertiary referral centers specializing in hernia care were compiled into 24 themes and grouped by four separate stages: Pre-Admission Optimization, Pre-Operative Care, Intra-operative Care, and Post-Operative Management.

Conclusion This article represents a multi-institutional review of ERAS protocols for ventral hernia repair and identifies common themes that may provide the framework for a unified ERAS protocol in hernia surgery. Future work may serve to develop societal guidelines defined specifically for enhanced recovery in ventral hernia repair.

Keywords Enhanced recovery after surgery · Enhanced recovery protocols · Ventral hernia · Abdominal wall reconstruction

Abbreviations

ACHQC	Abdominal Core Health Quality Collaborative
ASA	American Society of Anesthesiologists
BMI	Body mass index
CIWA	Clinical institute withdrawal assessment for alcohol
COPD	Chronic obstructive pulmonary disease
D51/2NS + 20 K	Dextrose 5% in sodium chloride 0.45% with 20 mEq/L potassium chloride
EHS	European Hernia Society
ERAS	Enhanced recovery after surgery
GDFT	Goal-directed fluid therapy
HbA1c	Glycosylated hemoglobin
IPOM	Intraperitoneal onlay mesh
IV	Intravenous
LFT	Liberal fluid therapy
LR	Lactate ringer's
MRSA	Methicillin-resistant staphylococcus aureus
NSAID	Non-steroidal anti-inflammatory drugs
ONS	Oral nutritional supplements
OSA	Obstructive sleep apnea
PCA	Patient controlled analgesia

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POD	Post-operative day
PONV	Post-operative nausea and vomiting
QI	Quality improvement
RCT	Randomized controlled trial
RFT	Restrictive fluid therapy
SSI	Surgical site infection
SSO	Surgical site occurrence
SSOPI	Surgical site occurrence requiring procedural intervention
TAP	Transversus abdominis plane
TAR	Transversus abdominis release
TID	Ter in die (three times daily)
UTI	Urinary tract infection
VTE	Venous thromboembolism

Introduction

Background and history of ERAS

Enhanced recovery after surgery (ERAS) protocols are evidence-based, perioperative care pathways aimed at minimizing the stress of surgery and maintaining normal physiology. The concept of enhanced recovery was first introduced in the 1990's after a series of studies using multimodal strategies to promote recovery after surgery showed a reduction in recovery time [1–3]. The ERAS Study Group (now the ERAS Society) was established in 2001 and went on to publish consensus guidelines for enhanced recovery after colonic resections in 2005. ERAS protocols have since become a mainstay in colorectal surgery after a meta-analysis of six randomized controlled trials (RCTs) discovered that the implementation of these protocols significantly reduced length of hospital stay and complication rates [4]. Since then, the ERAS Society has published guidelines for several surgical specialties.

For specialties without society guidelines, individual institutions have introduced their own ERAS protocols with varying components and inconsistent methodologies. This has led to notable variation in practices and is particularly evident in ventral hernia repair where significant heterogeneity exists in both the patient population and degree of surgical complexity. The Abdominal Core Health Quality Collaborative (ACHQC) is a collaboration of surgeons and institutions across the United States whose mission is to maximize the quality and value of care for patients who suffer from hernia disease [5]. The Quality Improvement (QI) Committee of the ACHQC represents a panel of hernia experts from across the country whose mission is to utilize the ACHQC data and network to improve patient outcomes in hernia care. In this review, we detail the ERAS practices from institutional members of the ACHQC. Our aim is to report and identify recurring themes within these protocols, provide a brief literature review for each theme, and finally end with recommendations from the ACHQC QI Committee providing the basis for a framework on evidence-based ERAS protocols.

Methods

Protocol acquisition and eligibility criteria

The ACHQC Quality Improvement (QI) committee solicited ACHQC institutional members for current ERAS protocols for hernia repairs. Protocols were not restricted by open or minimally invasive surgical approach as we felt recommendations may apply to the recovery following repairs of either approach. Submitted materials were comprised of published articles related to institution-specific practices, educational manuals, and guidebooks. For materials that referenced institutional order sets, efforts were made to include order set components. All submitted materials were screened by the authors and the QI committee. Only protocols specific to enhanced recovery after hernia repair were included. Six protocols were submitted to the ACHQC QI committee and following screening, all six contributing institutions and associated protocols were included.

Theme extraction

Data was independently extracted from each protocol and listed items within the protocol were classified as "elements", then assigned a topic. Any topic with ≥ 2 elements from separate institutions were labeled as a "theme." Themes were then grouped by stage in the patient care cycle. A total of 295 elements were compiled into 24 themes and grouped by four separate stages: Pre-Admission Optimization, Pre-Operative Care, Intra-operative Care, and Post-Operative Management. (Table 1).

Narrative summary

A narrative summary of each theme was generated. Each summary describes the number of protocols containing specific elements, explains what each element entailed and highlights areas where elements were similar in their details between protocols. In addition to the narrative summary, a brief review of current evidence is provided for readers who wish to create an evidence-based ERAS protocol. The narrative summary and review of evidence for each theme were developed initially by D.R. then reviewed and refined by the ACHQC QI committee through multiple rounds of iterative group discussions during which committee members offered feedback, suggested changes, and provided revisions. Each

Table 1 ERAS protocol themes by institution

	Institutions					
	1	2	3	4	5	6
Pre-operative optimization						
Nutrition evaluation	X	X		X	X	
Weight management	X	X		X	X	
Functional status assessment	X	X		X	X	
Smoking cessation	X	X		X	X	
Obstructive sleep apnea evaluation	X	X			X	
Diabetes mellitus evaluation/management		X		X	X	
Alcohol use evaluation/management	X	X			X	
MRSA screen	X	X		X	X	
Day of surgery care						
Pre-and intra-operative pain management	X	X	X	X	X	X
Post-operative nausea and vomiting prevention	X			X	X	
Extubation planning	X	X	X	X	X	
Intra-operative fluid management	X	X		X	X	
Post-operative care						
Post-operative pain management	X	X	X	X	X	X
Mobility	X	X	X	X	X	X
Venous thromboembolism prophylaxis	X	X	X	X	X	X
Post-operative antibiotics		X	X		X	
Diet	X	X	X	X	X	X
Laxative use	X	X	X	X		X
alvimopan use		X		X		
Post-operative fluid management	X	X	X	X	X	X
Urinary drainage	X	X	X		X	X
Drain care	X	X	X		X	X
Abdominal binder use	X	X	X	X	X	
Disposition planning				X	X	

section concludes with an ACHQC QI committee consensus statement, generated through a modified Delphi process.

Pre-admission optimization

Nutritional evaluation and metabolic optimization

Four out of six contributing institutions describe pre-operative nutritional evaluation and detail a nutritional supplement regimen. Three institutions rely on surgeon discretion to determine whether a patient would require pre-operative dietary supplementation. Evaluations include subjective determination of underweight or undernourished, or standard versus high-risk operation. One protocol uses objective data including albumin, prealbumin and Nutritional Risk Screening 2002 score (NRS-2002) to determine nutritional status and the need for oral nutritional supplements (ONS). The most common nutritional supplementation regimens prescribed are one ONS three times daily (TID) for five days or once daily for seven days.

Several clinical trials have demonstrated the benefits of pre-operative immune and metabolic modulation with ONS various patient populations [6–9]. However, evidence specific to the hernia population is admittedly absent. A recently published systematic review by the European Hernia Society (EHS) evaluated 1251 records and found no studies that specifically addressed preoperative nutrition in relation to ventral hernia repair or abdominal wall reconstruction [10].

ACHQC QI Committee Recommendation: There is a lack of specific evidence to support the use of ONS for pre-operative nutrition in ventral hernia repair. However, this intervention represents minimal risk to the patient and should be considered given the benefits in other surgical patient populations.

Weight management

Four institutions describe body mass index (BMI) cut-offs that trigger a referral to weight loss programs. Cut offs included: BMI > 30 and > 40. One protocol further stratified

BMI cut offs based on operative approach: BMI > 35 for open and > 40 for minimally invasive.

Obesity is an established risk factor for post-operative complications in ventral hernia repair, most notably recurrence and wound morbidity [11]. According to the most recent EHS guidelines for midline incisional hernias, targeted weight loss is recommended for "high" BMI patients, though without an explicit definition of "high" BMI. The same authors recognize that the possible risks associated with delaying surgery may outweigh benefits for the subset of patients who are unable to lose weight [12]. This risk is supported by a randomized controlled trial (RCT) conducted by Liang et al., in whicht patients randomized to a prehabilitation arm, comprised of dietary and fitness interventions , had an increased risk of emergent repair [13]. Though prehabilitation patients were more likely to achieve 7% total body weight loss and developed fewer hernias and complications at 30 days post-operatively, these benefits were not observed long term [14]. No consensus has been reached, nor currently exists, to support the use of a BMI "cut-off" for elective hernia repairs.

ACHQC QI Committee Recommendation: Pre-operative weight loss for elective ventral hernia repair remains a strong recommendation based on weak evidence. Short term benefit may exist in post-operative morbidity with weight loss, yet there is not enough evidence to support a specific BMI target. The operating surgeon must balance the risk of delaying hernia repair for weight loss with the risk of post-operative complications on an individualized basis.

Functional status assessment

Four institutions describe indications for pre-admission physical therapy referrals. Two protocols screen patients using the ability to climb two flights of stairs or subjective determination of diminished functional status or deconditioning. One protocol utilizes the Clinical Frailty Scale as a screening tool for all patients > 65 years of age.

The inclusion of mobility and/or frailty evaluation in the pre-operative stage typically serves as a global assessment of functional status and can be executed via professional observation, testing and/or self-reporting. Poor preoperative functional status has been shown to be a predictor of both all-cause and 90-day mortality in major elective intra-abdominal surgery [15], though not specific to hernia repairs. However, retrospective reviews, RCTs, and societal guidelines have demonstrated short-term benefits of pre-operative physical therapy in hernia patients [12, 14, 16].

ACHQC QI Committee Recommendations: Pre-operative physical therapy to improve functional status prior to elective ventral hernia repair represents a low-risk intervention with moderate evidence to support its use in abdominal surgery. If feasible, patients with poor baseline functional status should be recommended to undergo physical therapy pre-operatively.

Smoking cessation

Four institutions address smoking cessation with a standard recommendation of cessation of at least 30 days or four weeks prior to surgery. Two of the four institutions use urine testing prior to surgery to confirm cessation.

Smoking has long been considered a risk factor for post-operative complications after ventral hernia repair due to increased rates of wound [17–20], respiratory [17, 18], and infectious complications [18]. A Cochrane systematic review of 13 RCTs found a reduction in all complications and wound morbidity in smokers who underwent pre-operative smoking cessation greater than four weeks [21].

Recent data has emerged with conflicting evidence regarding smoking cessation when utilizing modern hernia repair techniques. A retrospective study examining patients at a single high-volume complex abdominal wall reconstruction center found that wound morbidity was mostly driven by increased rates of cellulitis and seroma while rates of surgical site infection (SSI), surgical site occurrences requiring procedural intervention (SSOPI), reoperation and all 30-day morbidity were not significantly increased [22]. Another study published from the same institution recently found no statistically significant difference in wound morbidity or reoperation rates comparing current smokers to never smokers [23].

ACHQC QI Committee Recommendations: Smoking cessation is strongly advised for overall health benefits to the patient, but the risk for post-operative complications in smokers in modern hernia repairs remains less clear. Smoking cessation should be counseled and recommended prior to offering elective hernia repair, particularly with onlay mesh, however, select patients with high-risk hernias may warrant repair without mandating smoking cessation.

Obstructive sleep apnea screening

Three institutions screen patients for obstructive sleep apnea (OSA) using the STOP-Bang Test. In two protocols, a score of > 3 is an indication for a pre-operative sleep study.

Unrecognized severe OSA is associated with increased risk of 30-day post-operative cardiovascular complications in patients undergoing major non-cardiac surgery [24]. In patients undergoing ventral hernia repair with component separation, OSA was found to be an independent risk factor for post-operative respiratory failure, which in turn was associated with increased risk of death, discharge to skilled nursing facility, length of stay, and total costs [25].

Screening patients at high risk of OSA offers the opportunity to mitigate the risk of respiratory failure through

early positive airway pressure therapy. A meta-analysis of 30,514 patients showed that patients with OSA who received positive airway pressure therapy pre and/or post-operatively reduced the risk of post-operative respiratory complications and unplanned ICU admissions [26].

ACHQC QI Committee Recommendations: Screening and treatment for OSA is recommended prior to elective ventral hernia repair.

Diabetes mellitus evaluation/management

Three institutions describe pre-operative management of diabetic patients based on glycosylated hemoglobin (HbA1c) levels. One protocol recommends that patients with an HbA1c > 7.4 be referred for endocrinology consultation. Another protocol recommends patients with a hemoglobin A1c between 8 and 10 defer surgery for one to two months and be referred to a primary care provider, specialty diabetes clinic or endocrinology specialist. In the same protocol, patients with HbA1c > 10 are recommended to defer surgery for three months and be referred to endocrinology specialist.

Peri-operative hyperglycemia is a proven risk factor for post-operative wound complications [27, 28]. As such, optimized glycemic control has been a mainstay in peri-operative practices and published guidelines [29, 30]. In ventral hernia repair, conflicting data that show both increased complications and no difference in outcomes when comparing patients with elevated glycosylated hemoglobin levels to non-diabetics [31, 32]. The current EHS midline incisional hernia guidelines recommend "good diabetic control" prior to surgery [12].

ACHQC QI Committee Recommendations: Glycosylated hemoglobin should be checked pre-operatively for patients with diabetes prior to elective ventral hernia repair. Although no cut off HbA1c threshold can be established, surgeons should develop appropriate post-operative glucose management plans.

Alcohol use evaluation/management

Three protocols describe screening for alcohol use using CAGE questionnaire and/or social history of alcohol use on pre-operative evaluation. For patients that screen positive on the CAGE questionnaire, it is recommended that an alcohol contract be signed between the clinician, patient and a third party for verification as a requirement prior to surgery. For patients who endorse a history of alcohol use on clinician screen, a post-operative Clinical Institute Withdrawal Assessment for Alcohol (CIWA) protocol is recommended.

Chronic alcohol use has been shown to depress adaptive immunity through increased T and B cell apoptosis and impaired activation and functioning of T-cells [33]. In surgical patients with chronic alcohol exposure, studies suggest an increased rate of post-operative morbidity, particularly in post-operative infections [34]. Following a metanalysis of 13 observational studies and five RCTs, two RCTs supported alcohol cessation for four weeks prior to surgery as a strategy to mitigate these effects [34]. No studies have been published investigating the impact of alcohol use or the utility of alcohol abstinence prior to ventral hernia repair.

ACHQC QI Committee Recommendations: Alcohol screening may be utilized at the discretion of the institution, however, with the lack of current evidence demonstrating improved outcomes, it is not recommended to mandate alcohol cessation prior elective hernia repair. Patients with cirrhosis and significant ascites need to be assessed individually.

MRSA screen

Four protocols screen patients for Methicillin-resistant Staphylococcus aureus (MRSA) colonization prior to surgery. Three protocols use a history of risk factors, such as prior infection, close contacts with MRSA or communal living, while one protocol uses pre-operative testing to determine colonization status. The most common recommended regimen is a daily chlorhexidine wash in conjunction with mupirocin ointment twice daily for five days prior to surgery.

Current literature for MRSA screening in ventral hernia repair is sparse. One study found that any prior history of MRSA infection, not just limited to the asymptomatic carrier state, conferred increased odds of 30-day SSI after ventral hernia repair. However, at two-year follow up, while SSO incidence was higher in patients with positive MRSA colonization compared to those without, this finding was not statistically significant [35].

ACHQC QI Committee Recommendations: There is no high-quality evidence to support MRSA screening in ventral hernia repair. Surgeons should follow institutional protocols for MRSA screening prior to elective surgery.

Pre-operative/intra-operative

Pre-operative and intra-operative pain management

All six included protocols detail practices for pre- and intra-operative pain control. Nearly all regimens were comprised of varying doses of acetaminophen, gabapentin, and a non-steroidal anti-inflammatory drug (NSAID) administered pre-operatively. The most common regimen consisted of acetaminophen 1 g, celecoxib 400 mg, and gabapentin 300 mg.

The determination of intra-operative regional analgesia is by surgeon discretion in four protocols, by anesthesia staff in

one protocol and not reported in one protocol. All protocols list a transversus abdominis plane (TAP) block as an option for regional analgesia. Two protocols also consider a quadratus lumborum block in lieu of a TAP block.

The use of TAP blocks and other regional blocks as part of an opioid-sparing multimodal regimen in ventral hernia repair has been studied in several retrospective reviews and two RCTs. Randomized studies have shown inconsistent results regarding pain scores and opioid consumption when comparing TAP blocks to placebo in open ventral hernia repair, with some studies demonstrating benefit while others show no difference [36, 37]. However, several retrospective reviews have supported use of TAP blocks for post operative pain reduction in open ventral hernia repair with component separation [38], transversus abdominus release (TAR) [39], and with laparoscopic [40] and robotic approaches [41] .

ACHQC QI Committee Recommendations: Multi-modal analgesia should be used in effort to reduce post-operative opioid consumption. TAP blocks and regional blocks may be useful adjuncts, their benefits are not clearly demonstrated in the existing literature.

Post-operative nausea and vomiting prevention

Pre-operative

Three protocols outline prophylaxis for post-operative nausea and vomiting (PONV). Two protocols use a single dose of a serotonin (5-HT3) receptor antagonist (ondansetron) and one uses a single dose of neurokinin (NK-1) receptor antagonist (aprepitant) in patients with a history of PONV.

Intra-operative

Two protocols administer a corticosteroid (dexamethasone) intra-operatively on emergence.

PONV is an extremely common occurrence, affecting 30–80% of patients [42]. Consensus guidelines have been developed that involve the use of prophylactic antiemetics and strategies to decrease baseline risk of PONV. These strategies include the use of propofol and sugammadex, avoidance of inhaled anesthetic agents, ensuring adequate hydration, and employing opioid sparing multimodal analgesia [43].

Multiple randomized controlled trials have shown that corticosteroids effectively reduce post-operative nausea and vomiting while providing additional benefits, such as a longer duration of action and lack of sedative properties [44]. Moreover, RCTs and metanalyses have been conducted directly comparing different single agent regimens, as well as varying single agents versus combination therapy. Combination antiemetic therapy has consistently been shown to be more efficacious than single therapy. Therefore, both the ERAS society and Society of Ambulatory Anesthesia recommend a multimodal approach to PONV prevention to maximize efficacy [43].

ACHQC QI Committee Recommendations: Multi-modal anti-emetics are recommended for patients at risk for PONV.

Extubation planning

Five protocols outline extubation planning. One protocol uses anesthesia staff discretion for extubation while three protocols use a plateau pressure change of >6 mmHg as an indication to remain intubated post-operatively. Two protocols go on to specify a plateau pressure change of >9 mmHg as an indication for paralysis and prolonged intubation of 24–48 h post-operatively. One protocol recommends surgeons also consider a history of COPD, dyspnea at rest, operative time >6 hours, ASA ≥ 4, albumin <3.5 and the indication for repair of a recurrent incarcerated hernia to guide post-operative extubation planning.

Studies have shown that patients undergoing abdominal wall reconstruction are at increased risk of respiratory complications. This phenomenon is attributed to reduced pulmonary compliance that occurs following the restoration of the abdominal domain and subsequent elevation in intra-abdominal pressure. [45, 46]. This rationale is supported by a study conducted by Blatnik and colleagues that found that a change in plateau pressure greater than or equal to 6 cmH_2O conferred a ninefold increase in risk of respiratory complications, while a change greater than or equal to 9 cmH_2O resulted in a nearly 12-fold increase [45]. Petro et al. later published a prospective series on 50 patients undergoing abdominal wall reconstruction and found that the increase in intra-abdominal pressure and concomitant decrease in abdominal perfusion pressure resolved by post-operative day (POD) 1 [46]. Taken together, these findings suggest that patients may benefit from prolonged intubation to minimize respiratory complications while physiologic changes associated with abdominal wall reconstruction equilibrate.

ACHQC QI Committee Recommendations: Intra-operative assessment of increased airway pressures via a change in plateau pressures from pre-fascial closure to post-fascial closure should be measured in patients undergoing abdominal wall reconstruction. A change of 6 mmHg or greater from pre- to post-fascial closure should be strongly considered for patients to remain intubated post-operatively. Surgeon and patient factors should also be considered.

Intra-operative fluid management

Four protocols describe intra-operative fluid management strategies. Two protocols recommend minimizing fluids while two protocols follow goal-directed fluid therapy.

Three strategies have been described in intra-operative fluid management: restrictive fluid therapy (RFT), goal-directed fluid therapy (GDFT) and liberal fluid therapy (LFT). RFT aims to minimize fluids to achieve a near-zero fluid balance, while GDFT targets monitored hemodynamic variables and uses end points of resuscitation to guide fluid administration. A recent network meta-analysis of RCTs was published by Yang et al. comparing these three modalities for intra-operative fluid management in elective non-vascular abdominal surgery. The authors concluded that GDFT may be superior to RFT or LFT due to reduced perioperative complications. However, it is important to highlight that this study is limited by significant heterogeneity leading to inconsistencies found by the authors on subsequent sensitivity analyses [47].

ACHQC QI Committee Recommendations: There exists little data to support recommendations for intra-operative fluid management in elective ventral hernia repair. GDFT represents a logical and moderate approach given the lack of evidence.

Post-operative

Post-operative pain management

All six protocols included detail post-operative multimodal analgesia strategies which is categorized and presented by analgesia type.

Continuous analgesia

Three protocols consider placement of an epidural to administer continuous spinal regional analgesia. One protocol considers a continuous intravenous (IV) lidocaine infusion post-operatively. Two protocols routinely use patient-controlled analgesia pumps (PCA) until POD3.

Scheduled Oral Analgesia.

All six protocols use a scheduled post-operative multimodal regimen of acetaminophen, gabapentinoid, and an NSAID.

Rescue analgesia

Most commonly, oral oxycodone is offered as rescue pain control. Doses range from 2.5–10 mg every 4–6 hours. Intravenous systemic narcotics are used as a last resort for rescue therapy.

Multimodal analgesia targets multiple pain receptors along the pain pathway by using a combination of analgesic medications from more than one pharmacological class. The combination of acetaminophen, gabapentin, and NSAIDs is often the cornerstone of multimodal analgesia. Acetaminophen and NSAIDs are favored for their widespread availability and affordability, while gabapentinoids have been shown to reduce post-operative opioid consumption as a component of multimodal therapy [48].

Multimodal analgesia in ventral hernia repair has been studied as part of ERAS protocols with favorable results [49–53]. The evidence supporting the use of epidural anesthesia in ventral hernia repair has been mixed. Previous work showed an association between a reduction in hospital length of stay and post-operative morbidity in patients receiving epidural anesthesia [54]. In contrast, a retrospective, propensity-matched review of 1,526 patients in the ACHQC database instead found an association with increased length of stay, post-operative complications, and worse pain scores [55]. Licari et al. also found that TAP blocks resulted in superior post-operative pain control when compared to epidural analgesia [56], which is somewhat contradictory to findings from other TAP block trials.

ACHQC QI Committee Recommendations: Multi-modal pain control post-operatively, including blocks and epidurals, should be used to limit systemic opioid use when possible.

Mobility

All six institutions report mobility goals for each post-operative day. Four protocols specify that the patient should at minimum be out of bed to bedside chair in the immediate post-operative phase. Three protocols further set a goal of ambulating at least once on POD 0. Ambulation goals beginning POD 1 range from three to five times daily. Two protocols routinely consult physical therapy (POD 0 or POD 1), while three protocols instead use surgical team discretion.

Several trials demonstrate an increased risk of venous thromboembolism with prolonged immobilization after surgery [57]. Particularly in abdominal surgery, delayed mobility is associated with increased post-operative pulmonary complications[58]. As a result, early mobilization is a well-established and integral component to enhanced recovery. However, compliance with post-operative mobility goals remains challenging. One proposed strategy to improve mobilization after major abdominal surgery is the use of technology, such as accelerometers and digital applications, to track and encourage mobilization [59, 60]. However, a recently published systematic review found that while observational studies have shown accelerometers increase mobilization and were associated with decreased complications, five out of six RCTs did not show benefit [59].

ACHQC QI Committee Recommendations: Early mobilization after elective ventral hernia repair is strongly recommended when safe. Consultation with physical therapy should be based on individual patient needs.

Venous thromboembolism prophylaxis

Pharmacological venous thromboembolism (VTE) prophylaxis is outlined in six protocols using a single dose of 5000 units of subcutaneous heparin administered pre-operatively. The timing of chemoprophylaxis initiation post-operatively varied from POD 0, POD 1, and by surgeon discretion. Chemical VTE prophylaxis post-operatively was recommended with enoxaparin 40 mg daily in normal renal function patients.

Thromboprophylaxis is a key element of post-operative care across all specialties. Large cohort studies using the ACS-NSQIP database have reported rates of VTE ranging from 0.5 to 0.92% following ventral hernia repair [61–63]. Risk factors cited in these studies include age, longer operative time, BMI, comorbidities, concurrent panniculectomy and component separation [61–65]. However, pharmacological thromboprophylaxis increases bleeding risk and some evidence suggests that blood transfusions may also increase risk of VTE [61]. Recently pooled data from major abdominal surgeries including ventral hernia repair found that chemoprophylaxis may safely be started within 24 hours after skin closure without an increased risk of bleeding or VTE [66].

ACHQC QI Committee Recommendations: There is significant evidence in favor of chemical VTE prophylaxis following abdominal surgery including ventral hernia repairs. It is recommended to provide either enoxaparin or heparin subcutaneously for VTE prevention post-operatively.

Post-operative antibiotics

Three protocols detail use of antibiotics post-operatively. Two protocols administer post-operative antibiotics in "high-risk" patients. One protocol continues the cefazolin while surgical drains are in place.

It has been theorized that surgical drains offer an avenue for pathogens to spread into wounds contributing to the development of SSIs. Prophylactic antibiotics with closed suction drains have been described as a strategy to mitigate these risks. However, in one meta-analysis by Weiss et al., the authors concluded that there was not sufficient data to suggest a clear indication for antibiotics with closed suction drains after ventral hernia repair [67].

ACHQC QI Committee Recommendations: There is no clear evidence to support the routine use of post-operative antibiotics solely for prophylaxis with drains in place.

Diet

All six protocols establish diet advancement plans. One protocol uses patient tolerance in combination with surgical team discretion for the advancement of diet, while the other institutional protocols highlight standard diet regimens by POD 0. Two protocols supplement diets with lactobacillus. Three protocols add nutritional supplements TID with meals with the start of a clear liquid diet.

Early enteral feeding has been shown to reduce the risk of post-operative infection and hospital length of stay in gastrointestinal (GI) surgery, without an increased risk of emesis [68]. While clear liquids are the diet of choice, one study in colorectal surgery found that starting patients on a low-residue diet post-operatively was associated with less nausea, faster return of bowel function and decreased length of stay [69]. However, one recently published RCT by Yao et al. reported that initiating a regular diet on POD 0 was associated with decreased patient tolerance compared to clear liquid despite no significant differences in nausea, bloating, pain, return of bowel function or length of stay [70]. The use of probiotics in abdominal surgery has also been shown to reduce postoperative ileus and time to return of bowel function and similarly confers minimal risk to patients [71], although not specifically studied in the hernia population.

ACHQC QI Committee Recommendations: Early post-operative enteral feeding should be encouraged when possible, however, surgeon discretion in complex cases may be used.

Laxative use

Four institutions place patients on a scheduled laxatives without one prevailing regimen. Most protocols use a permutation of two medications from three classes of laxatives: stimulant (sennakot), osmotic (polyethylene glycol, magnesium salts), or lubricant (docusate). A stimulant (bisacodyl) or osmotic (magnesium salt) laxative are used to supplement these regimens if GI function has not returned by a specified timepoint.

The etiology of post-operative constipation is multifactorial. Commonly cited factors include opioid use, decreased mobility and decreased oral intake. To prevent constipation and reduce duration of post-operative ileus, laxatives are routinely employed due to their favorable tolerability profile and affordability [72]. However, there is limited evidence [72]. As such, bowel regimens are often based on personal experience and preference.

ACHQC QI Committee Recommendations: There are no high-quality studies to support the routine use of laxatives in abdominal wall reconstruction.

Alvimopan use

Two institutions routinely use a peripherally acting μ-opioid receptor antagonist (alvimopan) as part of their enhanced recovery practice. In both protocols, alvimopan 12 mg PO is scheduled twice daily for seven days or until return of

bowel function. One protocol administers an additional dose of alvimopan pre-operatively.

μ-opioid receptor antagonists mitigate opioid-induced constipation by competitively binding μ receptors in the GI tract without affecting the analgesic effect of opioids. Several RCTs have studied the use of alvimopan after bowel surgery. In a meta-analysis including nine RCTs, alvimopan in conjunction with an enhanced recovery strategy has been shown to reduce time to hospital discharge order and GI recovery in patients undergoing open small bowel resection, large bowel resection and hysterectomy [73]. In the same study, dosing of 12 mg alvimopan once pre-operatively and twice daily for seven days showed superior results compared to 6 mg [73].

With respect to ventral hernia repair, alvimopan has been studied as part of the implementation of ERAS protocols versus standard control [49–52]. Three studies showed decreased time to return of bowel function [49–51] while one did not [52]. However, the impact of alvimopan alone in ventral hernia repair has not been studied.

ACHQC QI Committee Recommendations: Alvimpoan has evidence to support its use as part of an ERAS protocol without significant adverse side effects. Therefore, it should be utilized when possible.

Post-operative fluid management

All six institutions place patients on IV fluids post-operatively. While two protocols do not specify a fluid of choice, two protocols use Lactated Ringers and one protocol uses D51/2NS + 20 K. The most common rate of fluid administration is 75 cc/hr. Timing of cessation is evenly distributed between POD 1, POD 2 and based on patient tolerance of oral diet.

With respect to the selection of IV fluids, studies have shown an advantage of dextrose containing fluid in reduction of PONV compared to LR [74]. Additionally, ERAS guidelines have long established that conservative fluid strategies do not increase the risk of acute kidney injury, while volume overload may lead to increased post-operative complications and prolonged hospital stay [75]. However, a large database study using the ACS-NSQIP found a 1.4% incidence of acute kidney injury in open ventral hernia repair. Risk factors found on multivariate analysis included obesity, cardiovascular disease, diabetes, chronic kidney disease, hypoalbuminemia, prolonged operative time and intra-operative transfusion [76]. A retrospective study also found that TAR conferred nearly a two-fold risk of renal dysfunction compared to non-TAR patients [77].

ACHQC QI Committee Recommendations: There is mixed evidence to support strict guidelines in fluid management post-operatively following ventral hernia repair. Patients' clinical status should drive IV fluid therapy with goals for adequate end organ perfusion.

Urinary drainage

Five protocols indicate the use of indwelling urinary catheters with specified dates of removal. Three protocols state that foley catheters should be removed on POD 1, while one protocol discontinues use on POD 2.

Large retrospective analyses have shown that indwelling catheters in place longer than two days post-operatively are associated with increased in-hospital urinary tract infections (UTI), 30-day mortality and decreased likelihood of discharge home [78]. Following a Cochrane review on shorter versus longer urinary catheterization, ERAS guidelines have encouraged the removal of urinary catheters on the first post-operative day in low-risk patients [75, 79].

ACHQC QI Committee Recommendations: There is no data to drive removal of urinary catheters following ventral hernia repairs. It is recommended they are removed as early as possible at the surgeon discretion.

Drain care

Five protocols discuss drain management in the post-operative period. Three protocols specify varying frequencies of drain stripping while four protocols offer suggested criteria for removal. There was no consensus on the ideal frequency of stripping the drain. The most common criterion for drain removal was output of < 30–50 cc/24 h.

The use of prophylactic drain placement in ventral hernia repair remains controversial. In one meta-analysis including both primary and incisional ventral hernia repairs with retro-muscular or onlay mesh, drains were associated with increased risk of SSI [80]. However, in another meta-analysis specific to retro-muscular repair, drain placement was associated with decreased seroma and no difference in SSI, hematoma, SSO or SSOPI [81]. It is important to note that these metanalyses included laparoscopic, open and robotic approaches and shared three included studies [82–84]. Overall, these trials highlight that drains may have benefit in select operations. However, the specifics of drain care including frequency of stripping and timing of drain removal are areas in need of further investigation.

ACHQC QI Committee Recommendations: Drain use is indicated after large complex ventral hernia repairs requiring component separations. For small ventral hernias without creation of subcutaneous flaps, drains are not routinely indicated.

Abdominal binder use

Five protocols include use of abdominal binder in the post-operative period. Two of the five protocols begin use in the immediate post-operative period, however, do not describe the recommended duration of use. One protocol recommends an abdominal binder for patient comfort only, while another protocol recommends patients wear the binder around the clock except when showering.

The use of abdominal binders became popularized following a metanalysis published in 2021 that showed decreased rates of pain and longer distances walked in patients who wore an abdominal binder after elective surgery via a midline laparotomy [85]. Two RCTs have studied the use of abdominal binders in ventral hernia repair. Paasch et al. found statistically significantly less pain at rest on POD 1, 2 and 14 in patients undergoing laparoscopic intraperitoneal onlay mesh (IPOM) repair [86]. Conversly, Christoffersen et al. observed no statistically significant difference in post-operative pain during activity, activity limitation, general well-being, fatigue, or quality of life when compared to the no binder group in laparoscopic epigastric and umbilical hernia repair [87].

In both trials, individuals who wore an abdominal binder had less impairment of mobility; however, the findings were not statistically significant. It is important to highlight that these trials did not include the open approach and differed in time worn (7 days and nights vs. 2 weeks during the day), the sample size (n = 56 vs. n = 37), and the timing of pain measurement (POD 1, 2, 3, 7, and 30 during physical activity vs. POD 1, 2, and 14 at rest) [86, 87].

ACHQC QI Committee Recommendations: Abdominal binders are a low risk, cost effective intervention that may improve pain and mobility in patients after ventral hernia repairs. They are recommended in ERAS protocols for ventral hernias.

Disposition planning

Two institutions discuss disposition planning. One protocol mandates the verification of patient transportation and post-discharge requirements. Another protocol sets goal discharge of POD 4–5.

Early discharge planning ensures a safe transition of patient care from hospital to home, rehabilitation facility or long-term care. Communication and coordination are key to discharge planning and may include family members, nurses, social workers, occupational and physical therapists, case managers, caregivers, and at times, insurance companies. For surgical teams for whom these protocols often help guide, an ERAS protocol that highlights important considerations when coordinating discharge may contribute to timely and safe discharge.

ACHQC QI Committee Recommendations: Early disposition and discharge planning helps patients transfer care from hospital to home and therefore is recommended to be included in a comprehensive ERAS protocol.

Discussion

ERAS protocols in ventral hernia repair have demonstrated decreased length of stay [50, 52], faster return of bowel function [51, 51], fewer 90-day readmissions [50], decreased incidence of SSI [51], and less opioid use [53, 87] when compared to a standard practice. Three metanalyses have been published on this subject: Macedo et al. 2017, Lode et al. 2021, Sartori et al. 2021. After accounting for overlapping studies, these analyses together included six unique studies. All concluded that the implementation of ERAS protocols in abdominal wall reconstruction had a statically significant decreased length of stay compared to a standard practice [88–90]. The limitation of such studies lies within the heterogeneity in the protocols compounded by varying patient adherence. For example, Colvin et al. implemented a protocol comprised of five practices in the post-operative phase (pain control, diet, fluids, urinary drainage, and nasogastric tube avoidance) while Harryman et al. implemented a protocol of 15 elements including pre-operative risk stratification and intra-operative practices in addition to post-operative management [49, 91]. Our proposed framework includes over 20 practices that surgeons may consider when developing a protocol and highlights the heterogeneity present surrounding development of a comprehensive peri-operative care protocol. This heterogeneity likely stems from the lack of specific high-quality evidence specific to abdominal wall reconstruction to date.

Three articles have been published describing enhanced recovery practices in ventral hernia repair accompanied by relevant evidence and expert opinion [30, 92, 93]. However, these articles were published in 2014, 2018 and 2021 and provided only single institution-level practices. With the increasing body of evidence related to these topics, our study provides an update on current evidence and a broader view of contemporary practices across multiple institutions nationwide.

Limitations

Several limitations are important to address. Firstly, ACHQC QI Committee members have no formal experience in the development of ERAS protocols or ERAS guidelines. Furthermore, no ERAS protocols in hernia surgery are presently endorsed by any national or international hernia society. However, the aim of this article was to identify and

describe common themes from ERAS protocols currently in use, therefore we feel authors' lack of expertise in the development of ERAS protocols was not prohibitive. Secondly, though narrative summaries briefly describe evidence related to protocol elements, we did not conduct a systematic review of the evidence related to each theme and consequently should not be considered all-encompassing nor comprehensive. The goal of this article is not to provide evidence-based guidelines but instead highlight current practices and introduce the evidence and rationale supporting the included elements and themes of the protocols. We strongly encourage future work to seek to generate formal society guidelines. Additionally, consensus recommendations were generated by a modified Delphi process by the ACHQC Committee members. Because the evidence reviewed was not intended to be presented as though derived from a dedicated systematic review for each theme, we intentionally refrain from offering GRADE recommendations with our consensus statements. Lastly, current literature is primarily focused on the benefits of ERAS protocols and no studies exist targeting the potential complications of the implementation of ERAS protocols. Future work may seek to explore the potential drawbacks of ERAS protocols in ventral hernia repair.

Conclusion

This article represents a multi-institutional review of ERAS protocols for abdominal wall reconstruction through the ACHQC QI Committee. These recommendations are intended to be used for consolidating protocols into common themes and providing the framework for a unified ERAS protocol in hernia surgery. We feel this manuscript represents an important first step towards defining the practices currently being utilized and compiling supporting evidence when available for those utilized practices.

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Data availability We do not plan to make data publicly available.

Declarations

Conflict of interest Daphne Remulla, Joel F. Bradley III, Winnie Henderson, and Bridgette Kreuz have no disclosures. Ronald C. Lewis is a consultant for Intuitive Surgical, Inc. Lucas R. Beffa receives honoraria from Intuitive Surgical, Inc.

Ethical approval This study is a consensus statement from a professional society. This study did not involve patients and therefore did not require informed consent.

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