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The contribution of specific enhanced recovery after surgery (ERAS) protocol elements to reduced length of hospital stay after ventral hernia repair

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Abstract

Background Ventral hernia repair (VHR) is a commonly performed procedure that may be associated with prolonged hospitalization. Enhanced recovery after surgery (ERAS) protocols are intended to decrease hospital length of stay (LOS) and improve outcomes. This study evaluated the impact of compliance with individual VHR ERAS elements on LOS.

Methods With IRB approval, a medical record review (perioperative characteristics, clinical outcomes, compliance with ERAS elements) was conducted of open VHR consecutive cases performed in August 2013–July 2017. The ERAS protocol was implemented in August 2015; elements in place prior to implementation were accounted for in compliance review. Clinical predictors of LOS were determined through forward regression of log-transformed LOS. The effects of specific ERAS elements on LOS were assessed by adding them to the model in the presence of the clinical predictors.

Results Two-hundred and thirty-four patients underwent VHR (109 ERAS, 125 pre-ERAS). Across all patients, the mean LOS was 5.4 days (SD = 3.3). Independent perioperative predictors (P's < 0.05) of increased LOS were CDC Wound Class III/IV (38% increase above the mean), COPD (35%), prior infected mesh (21%), concomitant procedure (14%), mesh size (3% per 100 cm^2), and age (8% increase per 10 years from mean age). Formal ERAS implementation was associated with a 15% or about 0.7 days (95% CI 6%–24%) reduction in mean LOS after adjustment. Compliance with acceleration of intestinal recovery was low (25.6%) as many patients were not eligible for alvimopan use due to preoperative opioids, yet when achieved, provided the greatest reduction in LOS (− 36%).

Conclusions Implementation of an ERAS protocol for VHR results in decreased hospital LOS. Evaluation of the impact of specific ERAS element compliance to LOS is unique to this study. Compliance with acceleration of intestinal recovery, early postoperative mobilization, and multimodal pain management standards provided the greatest LOS reduction.

Keywords Ventral hernia repair · Enhanced recovery after surgery · Length of stay · ERAS compliance

Ventral hernia repair (VHR) is a surgical procedure to repair defects in the anterior abdominal wall. It is common procedure to correct an incisional hernia following abdominal laparotomy, a complication with an incidence greater than 10% [1, 2]. With over 2 million laparotomies performed in the USA, VHR is among the most frequently performed surgical procedure [3]. Inpatient VHR has been shown to generate a net loss of revenue for the provider, with revenue

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loss correlated to postoperative complications and the length of inpatient stay [4, 5].

Enhanced recovery after surgery (ERAS) pathways are a series of evidence-based protocols for postoperative care focused toward optimizing pain management and accelerating functional recovery [6, 7]. ERAS was initially found effective in reducing hospital length of stay (LOS) and postoperative morbidity in colorectal surgery, leading to investigation of its application and efficacy in VHR [6–10]. ERAS has been shown in early research to reduce LOS and readmission rates following VHR [7–11].

A confounding factor to the clinical application of ERAS research for VHR is variation among the amount and type of ERAS protocols utilized by investigators and the practical aspect of compliance among the multi-disciplinary care team and patients [12]. This creates uncertainty as to what elements of ERAS are most significantly related to the improved outcomes in LOS following VHR. Identifying the contribution of specific ERAS protocol elements to improved outcomes will better direct resources and clinical decisions when implementing ERAS in postoperative care. The purpose of this study is to evaluate the impact of compliance with individual VHR ERAS elements on LOS.

Methods

After receiving IRB approval, surgical databases at the University of Kentucky were searched for consecutive open VHR cases performed by one surgeon between August 2013 and July 2017. Initial or recurrent open VHR cases were included in the study (Current Procedural Codes 49560, 49561, 49565, 49566), while combined cases of VHR and planned ostomy reversals were excluded. Cases by only one surgeon were included to control for surgical technique, experience, and perioperative care of patients.

This study was conducted as a retrospective review of inpatient and ambulatory electronic medical records. Preoperative patient characteristics, including age, gender, body mass index (BMI), tobacco use at time of surgery scheduling (defined as any tobacco use within past 30 days), comorbidities (diabetes, chronic obstructive pulmonary disease, cancer, coronary artery disease, and/or hypertension), American Society of Anesthesiologists' (ASA) class, history of prior hernia repair, previous abdominal wall infection, previous mesh infection, and/or an open wound on the abdomen at the time of surgery were recorded for each case. Operative details, including duration of procedure, estimated blood loss, Centers for Disease Control and Prevention (CDC) wound class, component separation, and mesh type, size, and location, were also obtained from medical record data.

The ERAS protocol was formally implemented in August 2015. Eight of 15 ERAS elements thought to be influential on LOS, based on the surgeon's clinical judgment and experience, were examined. These included preoperative risk stratification and counseling, prophylaxis against thromboembolism, preoperative fasting and carbohydrate treatment, perioperative fluid management, prevention of intraoperative hypothermia, multimodal pain management, acceleration of intestinal recovery, and early postoperative mobilization (Table 1). The ERAS elements that were excluded from analysis were preoperative bowel preparation, MRSA prophylaxis, nutritional preparation, postoperative nausea and vomiting management, nasogastric intubation, urinary drainage with removal of Foley by postoperative day two, and postoperative glucose control (Table 2). After ERAS protocol review and preliminary regression analysis on the impact of individual elements on hospital LOS, the elements that were thought to be least impactful on postoperative recovery were excluded from the current study. While enforcement varied on a case-by-case basis, some elements were in place prior to ERAS implementation per hospital policy, including prophylaxis against thromboembolism. Other elements were encouraged but not enforced and varied on a case-by-case basis prior to ERAS implementation (Table 1). These were accounted for in the compliance review. Patients undergoing hernia repair after ERAS implementation received the standardized protocol in accordance with Table 1.

Compliance with each ERAS element was defined as follows: non-compliant (if none of the criteria in Table 1 for a protocol element were met), partially compliant (if one of two criteria were met), or full compliance (if both criteria were met). Some ERAS elements only had one potential criterion in which full compliance or non-compliance was assigned. The criteria for preoperative risk stratification and preoperative counseling were as follows: (1) patient BMI ≤ 40 kg/m^2 and (2) no tobacco use within the past 30 days of surgery scheduling. For prophylaxis against thromboembolism, the criteria were as follows: (1) one preoperative heparin or lovenox dose and (2) $>90\%$ compliance with scheduled postoperative heparin or lovenox doses. The criterion for preoperative fasting and carbohydrate treatment was supplementation with Gatorade at 4 h prior to arrival time for procedure. For perioperative fluid management, the criteria were as follows: (1) intraoperative fluids <2 L and/or (2) intraoperative fluids <5 cc/kg/hr. The criterion for prevention of intraoperative hypothermia was intraoperative temperature $\geq 36°$ C (96.8 F) throughout the procedure. For multimodal pain management, the criteria were as follows: (1) no scheduled opioids postoperatively and (2) greater than two modes of non-opioid multimodal postoperative pain management, including bupivacaine, acetaminophen, ibuprofen, ketorolac, lidocaine, gabapentin, cyclobenzaprine, diazepam, or baclofen. The criteria for acceleration of intestinal recovery were as follows: (1) one preoperative dose of almivopan and (2) postoperative almivopan BID until return

Table 1 Enhanced recovery after surgery protocol elements for ventral hernia repair included in analysis

	No.	Key element	Determination of adherence	Historical controls
ERAS elements included in analysis	1.	Preoperative risk counseling/ stratification	Weight to goal as recommended or BMI ≤ 40 kg/m^2 For smokers, notation that patient has ceased smoking × 4 weeks prior to surgery scheduling date	No systematic plan prior to ERAS implementation
	2.	Prophylaxis against thromboembolism	Preoperative and postoperative prophylaxis with heparin or lovenox	In place prior to protocol implementation per hospital policy
	3.	Preoperative fasting and carbohydrate treatment	Notation of last liquids taken as recorded by anesthesia or pre op nurses 4 h preop prior to surgery patient must drink Gatorade or receive IVF's	Not performed with historical controls
	4.	Perioperative fluid management	< 5 cc/kg/h or < 2 L of IVFs intraoperatively	Not performed with historical controls
	5.	Prevention of intraoperative hypothermia	Temperature ≥ 36 °C intraoperatively	No systematic plan prior to ERAS implementation
	6.	Multimodal pain management	No scheduled narcotics Multimodal therapy (epidural with bupivacaine, acetaminophen, ibuprofen, ketorolac, lidocaine, gabapentin, cyclobenzaprine, diazepam, or baclofen).	No systematic plan prior to ERAS implementation
	7.	Acceleration of intestinal recovery	Entereg (almivopan) ordered and administered as one dose preoperatively Given BID postoperatively until return of bowel function	Not performed with historical controls
	8.	Early mobilization	Notation that patient was out of bed and ambulating by end of POD #1	No systematic plan prior to ERAS implementation

of bowel function. For early mobilization, the criterion was patient ambulation by the end of postoperative day 1.

Bivariate analyses of LOS versus the clinical patient's comorbid and operative characteristics were performed using Chi-square or Fisher's exact tests with significance set at $P < 0.05$. Independent clinical predictors of hospital LOS were determined through forward regression of log-transformed LOS (P for entry < 0.05, for exit > 0.10). The effects of specific ERAS elements on LOS were then assessed by adding them to the regression model with adjustment for the independent clinical predictors. SPSS® version 23 (IBM® Corp., Armonk, NY) was used for all statistical analyses.

Results

During the time period August 2013 through July 2017, a total of 234 patients underwent VHR (109 with ERAS in place, 125 pre-ERAS protocol) meeting study inclusion criteria. Patient preoperative characteristics in pre-ERAS historical controls and patients undergoing ERAS protocol are shown in Table 3. The average patient age was 54.9 years (SD = 12.5), and the patients were equally divided male to female. The average patient BMI was 32.9 kg/m^2 (SD = 5.4). Almost half of patients were classified as former smokers (n = 109; 46.6%), and 22 patients had admitted to smoking within 4 weeks prior to date of surgery (9.4%). More than half of the patients had had at least one previous hernia repair (55.6%), and 31 patients (13.2%) had previous mesh infection.

Across all patients, the mean LOS was 5.4 days (SD = 3.3, Table 4). The strongest predictors of LOS include previous mesh infection, preoperative open wound, operative duration, estimated blood loss, Centers for Disease Control and Prevention (CDC) Wound Class, and type of mesh implanted. No differences were found in LOS due to gender, history of coronary artery disease, treatment for

Table 2 Enhanced recovery after surgery protocol elements for ventral hernia repair excluded from analysis

	No.	Key element	Determination of adherence	Historical controls
ERAS elements excluded from analysis	9.	Preoperative bowel preparation	Bowel preparation (clear liquids x 2 days prior to surgery) recommended only to patients with colostomy	In place prior to protocol implementation
	10.	Methicillin resistant *Staphylococcus Aureus* (MRSA) prophylaxis	Order for preoperative mupirocin intranasal ointment to be used x 5 days	Not performed with historical controls
	11.	Preoperative fasting and carbohydrate treatment	Notation of last liquids taken as recorded by anesthesia or pre op nurses 4 h preop prior to surgery you must drink Gatorade	Not performed with historical controls
	12.	Postoperative nausea and vomiting	Use of prophylactic antiemetics as appropriate	No systematic plan prior to ERAS implementation
	13.	Nasogastric intubation	NG tube placed in the OR removed prior to leaving OR	No systematic plan prior to ERAS implementation
	14.	Urinary drainage	Removal of Foley catheter by POD #2	No systematic plan prior to ERAS implementation
	15.	Postoperative glucose control	Blood glucose checked and sliding scale insulin utilized per hospital protocol	In place prior to protocol implementation per hospital policy

Table 3 Patient preoperative characteristics in pre-ERAS historical controls and ERAS patients

Characteristic	Historical control ($n=125$)	ERAS protocol ($n=109$)	*P* value
Median age (IQR) (years)	54 (46–64)	56 (47–65)	0.673
Female (%)	50%	49%	0.795
ASA class III or IV (%)	67%	66%	0.890
Diabetes (%)	28%	24%	0.551
COPD (%)	10%	7%	0.642
Cancer (%)	18%	28%	0.118
CAD (%)	14%	13%	0.849
HTN (%)	64%	62%	0.786
Smoking Status (%)			0.269
Never smoked	45%	43%	
Former smoker	43%	50%	
Current smoker	12%	7%	
BMI			0.059
< 30%	30%	36%	
30–39%	56%	59%	
≥ 40%	14%	5%	
0 prior hernia repairs (%)	42%	47%	0.105
1 prior hernia repair (%)	42%	29%	
≥ 2 Prior hernia repairs (%)	16%	24%	
Previous infected mesh	17%	9%	0.121
Preop. open wound	10%	7%	0.642
Previous abdominal wall infection	32%	35%	0.678

hypertension, smoking status, BMI, or history of previous hernia repair.

Independent perioperative predictors ($P < 0.05$) of increased LOS were CDC Wound Class III or IV (38% increase above the geometric mean), COPD (35%), prior infected mesh (21%), concomitant procedure (14%), mesh size (3% per 100 cm^2), and age (8% increase per 10 years from mean age).

Formal ERAS implementation was associated with a 15% or approximately 0.7 days (95% CI 6%–24%) reduction in mean LOS after adjustment. The percent of cases compliant vs. partially compliant vs. fully compliant with protocol stipulations and the risk-adjusted change in log LOS are presented in Table 5. Compliance with multimodal pain management and early mobilization were associated with 13% and 14% reduction in length of stay, respectively. Preoperative fasting/carbohydrate loading were not achievable in the majority of patients with 80.8% non-compliance. Compliance with acceleration of intestinal recovery was low (25.6%) as many patients were not eligible for alvimopan use due to preoperative opioids, yet when achieved, provided the greatest reduction in LOS (− 36%).

Discussion

In an effort to evaluate the benefits of ERAS compliance in relation to LOS following VHR, six perioperative factors predictive of LOS were identified. Factors predictive of increased LOS included a CDC wound class III/IV, COPD,

Table 4 Demographic and clinical predictors of LOS in bivariate analysis

Variable	Incidence	Mean LOS (SD)	*P* value
All patients	234	5.4 (3.3)	
Age, y			0.003
≤50	81	4.5 (2.0)	
51–60	72	5.4 (2.7)	
61+	81	6.3 (4.5)	
ASA class III or IV	156 (66.7%)	5.8 (3.6)	0.024
Treated diabetes	61 (26.1%)	6.2 (4.7)	0.026
COPD	20 (8.5%)	7.0 (2.9)	0.039
Previous infected mesh	31 (13.2%)	7.7 (3.3)	< 0.001
Preop. open wound	20 (8.5%)	8.1 (4.1)	< 0.001
Previous abdominal wall infection	78 (33.3%)	6.2 (3.3)	0.006
Operative duration, min			< 0.001
≤180	96 (41.0%)	4.3 (1.8)	
181–240	88 (37.6%)	5.2 (2.0)	
241+	50 (21.4%)	8.0 (5.3)	
Estimated defect size, cm^2			0.017
≤120	88 (37.6%)	4.6 (2.4)	
121–240	77 (32.9%)	5.9 (4.5)	
241+	69 (29.5%)	5.9 (2.4)	
Estimated EBL, mL			< 0.001
≤100	87 (37.2%)	4.2 (1.5)	
101–200	101 (43.2%)	6.1 (4.0)	
201+	46 (19.7%)	6.3 (3.5)	
CDC wound class			< 0.001
1	190 (81.1%)	4.9 (2.2)	
2	13 (5.6%)	5.4 (2.3)	
3	17 (7.3%)	8.7 (7.7)	
4	14 (6.0%)	8.6 (4.2)	
Mesh type: synthetic	118 (50.4%)	4.8 (2.1)	< 0.001
Biologic	19 (8.1%)	9.5 (7.7)	
Bioresorbable	97 (41.5%)	5.3 (2.5)	
Concomitant procedure	75 (32.1%)	6.4 (4.6)	0.002

Table 5 Compliance with enhanced recovery after surgery protocol elements, N = 234

Protocol element	% non-compliant	% partial compliance	% compliant	Risk-adjusted[a] change in log-LOS (95% CI)
Preoperative risk counseling/stratification	0.4	14.5	85.0	1.01 (0.87–1.17)
Prophylaxis against thromboembolism	12.4	0	87.6	1.13 (0.96–1.33)
Preoperative fasting and carbohydrate treatment	80.8	0	19.2	0.90[e] (0.77–1.01)
Perioperative fluid management	41.9	2.1	56.0	0.87[c] (0.79–0.96)
Prevention of intraoperative hypothermia	40.2	0	59.8	0.91[e] (0.82–1.01)
Multimodal pain management	2.6	36.3	61.1	0.87[d] (0.78–0.97)
Acceleration of intestinal recovery	13.2	61.1	25.6	0.64[b] (0.54–0.77)
Early mobilization	47.9	0	52.1	0.86[c] (0.78–0.96)

[a]Adjusted for independent clinical predictors

[b]linear regression versus log-transformed LOS $P < 0.001$; [c]$P < 0.01$, [d]$P < 0.05$; [e]$P \leq 0.10$

history of infected mesh, concomitant procedures, mesh size, and age. Each of these factors is associated with increased patient complexity. The type of mesh used also correlates with the operative complexity, as 8.1% of our patients were felt to be at higher risk category for SSI or mesh complications resulting in the utilization of a biologic mesh as opposed to synthetic (50.4%) or bioresorbable (41.5%) (Table 4). Statistically adjusting for these factors, formal implementation of ERAS protocols contributed to an overall 15% reduction in mean LOS. With independent consideration of each of the eight protocol components, perioperative fluid management (− 13%), multimodal pain management (− 13%), early mobilization (− 14%), and acceleration of intestinal recovery (− 36%) were identified to significantly reduce LOS.

Among the ERAS elements, acceleration of intestinal recovery provides a significant opportunity in patient management as suggested by the magnitude of its effect on LOS relative to the other notable ERAS factors. With the goal of intestinal recovery, our institution utilizes alvimopan, a commonly employed drug that is used to decrease postoperative ileus following colorectal procedures and accelerate recovery [13]. In a study by Adam et al., the authors evaluated the benefits of alvimopan in reducing the incidence of postoperative ileus following colorectal surgery. Application of alvimopan leads to significant improvements across a variety of measures including a reduction in the rate of ileus, accelerated bowel recovery, and an overall reduction in hospital stay duration [14]. Despite cost concerns associated with an alvimopan regimen, administration also contributed to an approximate $1500 decrease in total hospital cost [14]. Our analysis does encourage the application of alvimopan, with independent analysis supporting a 36% decrease in LOS when employed for intestinal recovery. While intestinal recovery contributed to a significant reduction in LOS following hernia repair, only a quarter of our patient cohort was eligible for treatment as a result of preoperative opioid use. Within the ineligible group, a significant portion had been previously prescribed opioids for chronic back pain, which was further supplemented by hernia-related pain management provided by external healthcare providers. Although cessation and avoidance of opioids prior to repair should be emphasized for optimization of postsurgical recovery and discharge, achieving this goal would require coordinated effort among healthcare providers.

The use of thromboembolism prophylaxis within VHR procedures presents a complex consideration of optimization. A thromboembolic event during hernia repairs is widely recognized to be a considerably rare event with a reported 90-day perioperative rate of 0.18% [15]. Prior findings evaluating the incidence of thromboembolism have indicated that prophylaxis provides minimal reductions in thrombotic events during hernia repairs, discouraging use in low-risk patients [16]. While our study does suggest that increased blood loss, an inherent byproduct of prophylaxis, may contribute to an increased LOS, consideration of catastrophic thrombotic events may warrant the extended hospitalization duration. Furthermore, the risks associated with prophylaxis are rather minimal during hernia repair in comparison with more invasive procedures, encouraging preventative measures. With the goal of minimizing LOS, the choice of preoperative, perioperative, and postoperative thromboembolism prophylaxis presents an opportunity for optimization and comprehensive evaluation of patient characteristics.

Regarding patient characteristics, risk counseling and stratification provided negligible impact on LOS. Achieving a BMI less than 40 and smoking cessation 30 days prior to surgery were the main criteria for stratification. Both smoking cessation and obesity are the few preoperative variables that may be optimized prior to surgery. Obesity has been linked to a wide variety of postprocedural complications, including wound complications, hernia recurrence, and surgical site infections [17, 18]. In a similar manner, tobacco use prior to surgery has been observed to significantly increase the likelihood of wound complications, hernia recurrence, and infection [19, 20]. While smoking cessation and weight management did not provide a short-term benefit in reducing LOS following surgical repair, the utility of these stratification criteria has been supported by more long-term analyses, given that the complications associated with these factors frequently result in readmission following repair.

The main limitations of this study were sample size, which may have limited statistical significance associated with certain ERAS components, and the choice of ERAS factors. Preoperative fasting and carbohydrate treatment and prevention of intraoperative hypothermia were suggestive of reducing LOS but did not meet statistical significance. Additionally, thromboembolism prophylaxis was suggestive of an increased LOS but was limited in a similar manner.

Conclusions

Implementation of an ERAS protocol for VHR results in decreased hospital LOS. Evaluation of the impact of specific ERAS element compliance to hospital LOS in VHR is unique to this study. Compliance with acceleration of intestinal recovery, early postoperative mobilization, and multimodal pain management standards provided the greatest reductions in LOS.

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Compliance with ethical standards

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