Multicenter Observational Study Examining the Implementation of Enhanced Recovery Within the Virginia Surgical Quality Collaborative in Patients Undergoing Elective Colectomy

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BACKGROUND: The American College of Surgeons (ACS) NSQIP Virginia Surgical Quality Collaborative (VSQC) exists to improve surgical outcomes through multi-institutional collaboration. Enhanced recovery (ER) protocols improve morbidity and reduce length of stay (LOS) after elective surgery. We hypothesized implementation of ER through VSQC would reduce postoperative complications and LOS in patients undergoing elective colectomy. Our objective was to evaluate whether standardization of care based on evidenced-based practices in healthcare settings across multiple institutions improved outcomes.

STUDY DESIGN: In 2013, VSQC incrementally implemented ER for patients undergoing elective colectomy at participating institutions. Institutions shared protocols, order sets, educational materials, and met semi-annually to discuss progress. Risk-adjusted ACS NSQIP data (January 1, 2012 through December 31, 2016) was queried in 4 participating hospitals. The association of ER with surgical outcomes was evaluated with a before and after ER implementation analysis and multivariable logistic regression modeling with a priori selection of clinically relevant variables.

RESULTS: There were 2,438 consecutive colectomies included in analysis (1,035 pre-ER/1,403 post-ER). In the post-ER implementation patient cohort, relatively more patients were treated laparoscopically (68%) compared with the pre-ER cohort (52%) ($p < 0.001$). Median LOS decreased from 5 to 4 days after ER implementation in patients undergoing open colectomy ($p < 0.001$), although total complications were similar in frequency (23% vs 22%). Laparoscopic patients had a reduced LOS (4 vs 3 days; $p < 0.001$), 30-day readmissions (12% vs 8%; $p = 0.01$), and total complications (16% vs 9%; $p < 0.001$) after ER implementation. In multivariable models, American Society of Anesthesiologists Physical Status Classification, hypertension, smoking, ER, and laparoscopy were independently associated with complication risk.

CONCLUSIONS: Implementation of ER across VSQC was associated with reduction in LOS and complications in patients undergoing elective laparoscopic colectomy. (J Am Coll Surg 2019;229:374–382.

CME questions for this article available at http://jacscme.facs.org

Disclosure Information: Authors have nothing to disclose. Timothy J Eberlein, Editor-in-Chief, has nothing to disclose.

Disclosures outside the scope of this work: Dr Fogel receives payments for being on the advisory board of Monarch Medical and the clinical evaluation committee of Edwards Lifesciences. Dr Reines receives payments from multiple law firms for expert testimony.

Presented at American College of Surgeons 104th Annual Clinical Congress, Boston, MA, October 2018.

Received January 29, 2019; Revised April 26, 2019; Accepted April 26, 2019.

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https://doi.org/10.1016/j.jamcollsurg.2019.04.033
ISSN 1072-7515/19

Abbreviations and Acronyms
ACS = American College of Surgeons
ER = enhanced recovery
LOS = length of stay
VSQC = Virginia Surgical Quality Collaborative

As the primary treatment for colorectal cancer, complicated diverticular disease, and medical refractory inflammatory bowel disease, colorectal resections rank among the most ubiquitous and frequently performed operations throughout the US. Complications after colectomy are common, occurring in up to 25% of patients and costing an estimated $150 million annually.[1-3] For those reasons, colorectal surgery has emerged as a standard marker of quality in the acute care setting.

Enhanced recovery (ER) represents a philosophy of perioperative care based on extensive preoperative education, rational fluid management with carbohydrate loading and judicious use of IV fluids, multimodal analgesia with avoidance of opioids, and immediate initiation of feeding with encouragement of physical activity. More than 10 case-control studies including more than 3,000 patients have reported shortened recovery time, reduced rates of ileus, and profound reductions (>80%) in opioid consumption in ER patients in a variety of surgical patient populations.[4-21] However, many of the published reports within the US have been isolated to single-institution experiences within large academic institutions with plentiful resources. Implementation of ER within varying healthcare settings across multiple institutions and practice patterns might prove more challenging.

The American College of Surgeons NSQIP provides a framework for more than 45 collaborative groups designed to promote data sharing and provide a platform for collaborative quality improvement efforts. The Virginia Surgical Quality Collaborative (VSQC) brings together a group of hospitals in Virginia that vary in size, affiliation, and structure. Beginning in 2013, the VSQC chose ER as a quality improvement project and incrementally implemented it for patients undergoing elective colorectal surgery at participating institutions during the ensuing 3 years. We hypothesized that implementation of ER through the VSQC would reduce postoperative complications and length of stay (LOS) in patients undergoing elective colectomy.

METHODS

Virginia Surgical Quality Collaborative

The VSQC is a regional collaborative within American College of Surgeons (ACS) NSQIP currently composed of 6 institutions throughout the state of Virginia. Collaborative representatives from each participating institution meet twice a year, once at the annual ACS NSQIP conference and again at the Virginia Chapter of ACS. Throughout the year, conference calls were held to discuss this ongoing quality improvement initiative. Membership in the collaborative has varied over the years as some hospitals join and some withdraw. Sites that had abstracted at least 1 year of ACS NSQIP data were eligible to participate in the study. Four institutions have remained with the collaborative consistently during the last 5 years: Carilion Clinic (870-bed academic medical center), Inova-Fairfax (947-bed community hospital), University of Virginia Medical Center (700-bed academic medical center), and Winchester Medical Center (455-bed community hospital). The current data set includes consecutive patients undergoing colectomy, included in the institution's ACS NSQIP semiannual report, in these 4 hospitals during the study period.

Enhanced recovery implementation

Beginning in 2013, VSQC chose ER as a quality improvement project and incrementally implemented it at participating institutions. Institutions shared protocols, order sets, and patient and staff educational materials, and met semi-annually to discuss progress and share information. In some cases, institutional representatives visited other collaborative institutions to get additional onsite education. Each institution developed its own individual protocol incorporating the main tenets of ER, including extensive preoperative patient education/engagement, preoperative carbohydrate loading, multimodal pain management strategy with opioid minimization, maintenance of euvolemia, promotion of minimally invasive surgical techniques, early feeding, and ambulation. Common ER elements across sites are included in Table 1. The choices of specific ER protocol elements were left to the individual institutions to facilitate acceptance and cooperation of local providers. Sites monitored compliance with their ER protocols, which are included in eDocument 1. No other VSQC quality projects were initiated during the study period.

Table 1. Enhanced Recovery Elements Common across Virginia Surgical Quality Collaborative Sites

ER element	Hospital 1	Hospital 2	Hospital 3	Hospital 4
Preoperative education	Educational material	Educational material, prehabilitation program	Educational material	Educational material
Preoperative analgesia	Celecoxib, gabapentin, acetaminophen	Celecoxib, gabapentin	Celecoxib, gabapentin, acetaminophen	Celecoxib, gabapentin, acetaminophen
Intraoperative fluids	Fluid monitoring	Goal-directed therapy	Goal-directed therapy	Goal-directed therapy
Intraoperative pain management	Liposomal bupivacaine incision infiltration	Duramorph spinal, ketorolac, acetaminophen, lidocaine infusion for 24 h	Duramorph spinal, lidocaine infusion continue to POD 2	Duramorph spinal, lidocaine infusion continue to POD 2
Postoperative diet	Clear liquids day of operation	Clear liquids day of operation	Clear liquids night of operation	Clear liquids day of operation
Postoperative activity	Ambulation day of operation, HOB 30 degrees	Ambulation day of operation	Ambulation night of operation, HOB 30 degrees	Ambulation night of operation, HOB 30 degrees
Postoperative analgesia	Acetaminophen, oxycodone, ketorolac, ibuprofen, tramadol	Acetaminophen, ketorolac	Acetaminophen, oxycodone, celecoxib	Acetaminophen, celecoxib, oxycodone oral (PRN), hydromophone oral (PRN)
Postoperative gastrointestinal recovery	—	Alvimopan for 7 days	Alvimopan for 7 days	—

ER, enhanced recovery; HOB, head of bed; POD, postoperative day; PRN, pro re nata/as needed.

Study design

Given the de-identified nature of the data, the IRBs at all participating institutions deemed the study exempt. This before and after ER implementation cohort study included consecutive elective colon resections included in ACS NSQIPs Colectomy Procedure Targeted Module (Current Procedural Terminology codes 44140 to 44147, 44150, 44151, 44160, and 44204 to 44210) performed between January 1, 2012 and December 31, 2016 at the Carilion Clinic, Inova Fairfax Hospital, University of Virginia Health System, and Winchester Medical Center. Urgent/emergent procedures were excluded. De-identified data were obtained from each institution, including demographic, procedure, and complication data as provided in the ACS NSQIP database. Definitions for each NSQIP variable can be found at https://www.facs.org/~/media/files/quality%20programs/nsqip/nsqip_puf_userguide_2016.ashx. Preoperative risk factors were coded as follows: diabetes included patients on insulin and non-insulin medications; dependent functional status included totally and partially dependent patients; and dyspnea on exertion included dyspnea with moderate exertion and at rest. Postoperative 30-day morbidity excluded cases with events present at the time of operation for superficial, deep, and organ space infections; pneumonia; urinary tract infections; and sepsis. Unplanned readmission within 30 days of the surgical procedure was analyzed.

Each institution implemented their specific ER protocol at separate time points (one in 2013, two in 2014, and one in 2016). Institutions remained de-identified during data analysis, but hospitals were randomly assigned an identifier to explore pre- and post-ER implementation case distribution and hospital differences in logistic regression modeling. However, because case volume and ER protocol start date could be used to identify specific hospitals, protocol implementation, and outcomes were not linked or reported. Each institution reported the year and the quarter of the operation, as well as whether the patient underwent the procedure before or after ER implementation at the respective institution. Patients were stratified into 2 groups: pre-ER if the procedure was performed before the date ER was implemented at the respective institution, and post-ER if the procedure was performed after the date that ER was implemented at the respective institution. Risk adjustment for the analyses of 30-day complications (primary outcomes variable) was done by comparing the number of observed events with the ACS NSQIP calculated probabilities of 30-day morbidity and derived expected events, via the observed to expected ratio.

A before and after ER implementation cohort analysis was used to evaluate the association of ER implementation with surgical outcomes within the collaborative. Outcomes for the collaborative as a whole are also reported over time, according to the year of operation. The primary end point of the study was occurrence of a complication within 30 days after operation. Secondary outcomes included 30-day postoperative complications based on ACS NSQIP definitions (surgical site infection, wound disruption, postoperative pneumonia, unplanned intubation, pulmonary embolism, renal insufficiency, postoperative hemodialysis, cerebrovascular accident, cardiac arrest, myocardial infarction, sepsis/septic shock, and other postoperative occurrences), LOS, and 30-day unplanned readmissions. Univariate analyses were conducted to compare differences in baseline patient factors, procedural characteristics, and postoperative outcomes between patients treated before and after ER implementation. Differences were compared using the chi-square test for categorical variables, Wilcoxon rank-sum test for continuous variables, and medians. Logistic regression modeling with a priori selection of clinically relevant variables determined by colorectal experts was used to investigate the association of ER with the occurrence of complications. Categorical variables are reported as n (%) and continuous variables presented as median (interquartile range). A p value of 0.05 was the threshold for statistical significance.

Analysis was completed using IBM SPSS Statistics for Windows, version 25 (IBM Corp).

RESULTS

There were 2,438 consecutive colectomies included in the analysis (1,035 pre-ER and 1,403 post-ER). In the post-ER implementation patient cohort, relatively more patients were treated laparoscopically (68%) compared with the pre-ER cohort (52%) ($p < 0.001$). Due to this significant shift in surgical technique from open to laparoscopy during the course of the study period, open and laparoscopic cases were analyzed separately (Fig. 1). There were significant differences in diagnosis and preoperative risk factors in patients undergoing open colectomy after ER implementation, with significantly more patients with inflammatory bowel disease, disseminated cancer, and on steroid medication in the post-ER group. Despite that, the ACS NSQIP predicted risk of morbidity was lower in the post-ER group (Table 2). For laparoscopic patients, there was a higher proportion of patients with American Society of Anesthesiologists classification scores ≥ 3 in the post-ER group, but the ACS NSQIP predicted risk of morbidity was lower in the post-ER group (Table 2). Surgeon staffing remained stable throughout the 5-year study period. Three surgeons joined colorectal practices and 1 surgeon left, but their percent of laparoscopic cases did not differ significantly from other colorectal surgeons at their institution (data not shown).

Outcomes before and after implementation of ER for open and laparoscopic colectomy are summarized in Table 3. Median LOS decreased from 5 to 4 days ($p = 0.001$; mean decreased 7.0 to 6.7 days) after ER implementation in patients undergoing open colectomy. In addition, there was a 50% reduction in superficial/deep surgical site infection (13% vs 7%; $p < 0.001$). However, the overall rate of complications remained relatively unchanged before and after ER implementation (23% vs 22%, respectively). Median ACS NSQIP estimated probability of morbidity decreased in the post-ER implementation cohort compared with pre-ER, for open (19.4% to 17.1%; $p < 0.001$) and laparoscopic (9.8% to 8.3%; $p < 0.001$) colectomy. The observed to expected ratio for complications in open colectomy patients was 1.17 before and 1.29 after ER implementation based on the reduction in the ACS NSQIP predicted risk of complications during the course of the study period. Patients undergoing laparoscopic resection had the largest gains with significant reduction in LOS (4 vs 3 days; $p < 0.001$), 30-day readmission (12% vs 8%; $p = 0.01$), and surgical site infection (8% vs. 2%; $p < 0.001$) in the post-ER group. There was a reduction in complications after implementation of ER in patients undergoing laparoscopic colectomy (16% vs 9%; $p < 0.001$). The observed to expected ratio for complications was 1.60 before and 1.03 after ER implementation in patients undergoing laparoscopic colectomy.

The VSQC data stratified by year of operation are shown in Figures 2 and 3 for open and laparoscopic colectomy, demonstrating a sustained improvement of

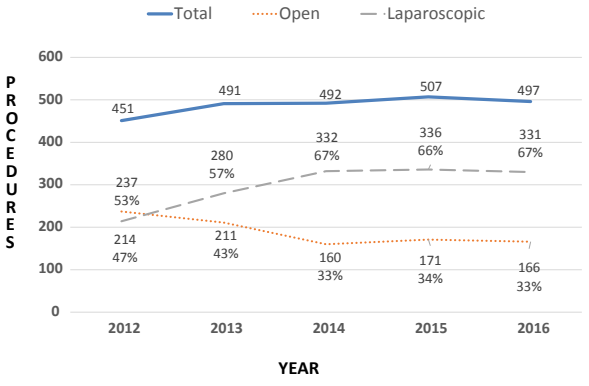

Figure 1. Distribution of laparoscopic vs open colectomy in Virginia Surgical Quality Collaborative from 2012 to 2016.

1 day in LOS for both open and laparoscopic colectomy after ER implementation in addition to significant improvements in complications and 30-day readmission rates in laparoscopic colectomy over time. The distribution of cases pre-ER implementation by hospital ranged from 13% to 49% and post-ER implementation from 2% to 53%. Results from logistic regression models adjusted for age, race, BMI, diabetes mellitus, smoking, hypertension, functional health status, American Society of Anesthesiologists Physical Status Classification, hospital, ER, and laparoscopy indicated that American Society of Anesthesiologists of ≥3, hypertension, current smoker, ER protocol, and laparoscopy were independently associated with complication risk (Table 4). The C-statistic for the model was 0.67.

DISCUSSION

These data suggest significant quality improvement through collaboration after incorporation of ER principles in patients undergoing elective colon surgery. Given the association among perioperative outcomes, long-term survival, and quality of life, these data serve to highlight the importance of collaborative efforts focused on short-term perioperative outcomes.[22] Although the success of regional collaboration in improving outcomes after operations has been well-described,[23-26] as has the compliance with ER implementation,[27] this study represents the first to evaluate ER implementation specifically for regional clinical outcomes after open and laparoscopic colectomy procedures.

Although the majority of data supporting the efficacy of ER comes from single institutional experience, largely in

Table 2. Demographics and Risk Factors of Patients Undergoing Open and Laparoscopic Colectomy Pre- and Post-Enhanced Recovery Implementation

	Open colectomy			Laparoscopic colectomy		
Variable	Pre-ER (n = 492)	Post-ER (n = 453)	p Value	Pre-ER (n = 543)	Post-ER (n = 950)	p Value
Age, y, median (IQR)	63 (53–72)	64 (53–73)	0.23	61 (51–69)	60 (51–70)	0.44
Male sex, n (%)	232 (47)	223 (49)	0.54	245 (45)	415 (44)	0.60
Race, n (%)						
African American	42 (8)	34 (8)	0.57	43 (8)	75 (8)	0.99
White	432 (88)	381 (84)	0.10	464 (86)	782 (82)	0.11
Asian/other	14 (3)	19 (4)	0.40	22 (4)	41 (4)	0.99
Not reported	4 (1)	19 (4)	0.003	14 (3)	52 (6)	0.01
BMI, kg/m^2, median (IQR)	27 (23–32)	26 (22.9–32.0)	0.13	24 (24–31)	27 (24–31)	0.47
Diabetes, n (%)	98 (20)	79 (17)	0.33	65 (12)	122 (13)	0.65
Smoker, n (%)	92 (19)	95 (21)	0.38	61 (11)	127 (13)	0.22
Dyspnea on exertion, n (%)	41 (8)	43 (10)	0.52	22 (4)	39 (4)	0.99
Hypertension, n (%)	261 (53)	221 (49)	0.22	257 (47)	427 (45)	0.46
Dependent functional status, n (%)	10 (2)	9 (2)	0.99	5 (0.9)	4 (0.4)	0.22
Severe COPD, n (%)	32 (7)	32 (7)	0.71	10 (2)	33 (4)	0.06
Disseminated cancer, n (%)	41 (8)	56 (12)	0.04	16 (3)	29 (3)	0.83
Steroid, n (%)	33 (7)	49 (11)	0.03	32 (6)	70 (7)	0.27
ASA ≥3, n (%)	263 (54)	268 (59)	0.08	222 (41)	452 (48)	0.01
Contaminated/dirty wound, n (%)	111 (23)	91 (20)	0.35	50 (9)	91 (10)	0.80
Diagnosis, n (%)						
Neoplasm	294 (60)	266 (59)	0.73	328 (60)	563 (59)	0.68
Diverticulitis	90 (18)	68 (15)	0.17	146 (27)	236 (25)	0.37
Vesicovaginal fistula	21 (4)	21 (5)	0.82	7 (1)	15 (2)	0.65
Inflammatory bowel disease	38 (8)	53 (12)	0.04	35 (6)	81 (9)	0.14
Other	49 (10)	45 (10)	0.99	27 (5)	55 (6)	0.41
ACS NSQIP estimated probability of morbidity, median (IQR)	0.194 (0.15–0.24)	0.171 (0.13–0.21)	<0.001	0.098 (0.08–0.12)	0.083 (0.07–0.11)	<0.001

ACS, American College of Surgeons; ASA, American Society of Anesthesiologists; ER, enhanced recovery; IQR, interquartile range.

Table 3. Outcomes Data in Patients Undergoing Open and Laparoscopic Colectomy Pre- and Post- Enhanced Recovery Implementation

	Open colectomy			Laparoscopic colectomy		
Outcome	**Pre-ER (n = 492)**	**Post-ER (n = 453)**	**p Value**	**Pre-ER (n = 543)**	**Post-ER (n = 950)**	**p Value**
Length of stay, d, median (IQR)	5 (4–7)	4 (3–7)	0.001	4 (3–5)	3 (2–4)	<0.001
Readmission, n (%)	71 (14)	74 (16)	0.42	67 (12)	78 (8)	0.01
Death, n (%)	5 (1)	7 (2)	0.49	1 (0.2)	4 (0.4)	0.52
Superficial/deep SSI, n (%)	65 (13)	30 (7)	<0.001	43 (8)	14 (1)	<0.001
Organ space SSI, n (%)	25 (5)	33 (7)	0.16	29 (5)	40 (4)	0.33
Pulmonary embolus/deep vein thrombosis, n (%)	17 (4)	12 (3)	0.42	7 (1)	15 (2)	0.65
Progressive renal insufficiency, n (%)	7 (1)	12 (3)	0.19	1 (0.2)	5 (0.5)	0.37
Acute renal failure, n (%)	5 (1)	3 (1)	0.62	1 (0.2)	0 (0.0)	0.17
Urinary tract infection, n (%)	11 (2)	13 (3)	0.49	15 (3)	21 (2)	0.47
MI, n (%)	6 (1)	3 (1)	0.43	1 (0.2)	2 (0.2)	0.99
Postoperative bleeding requiring transfusion, n (%)	51 (10)	43 (10)	0.64	35 (6)	39 (4)	0.05
Sepsis, n (%)	16 (3)	10 (2)	0.30	7 (1)	10 (1)	0.73
Pneumonia, n (%)	10 (2)	12 (3)	0.54	1 (0.2)	3 (0.3)	0.72
Unplanned return to operating room, n (%)	36 (7)	27 (6)	0.42	28 (5)	47 (5)	0.53
Any complication, n (%)	112 (23)	100 (22)	0.80	85 (16)	82 (9)	<0.001
ACS NSQIP estimated probability of morbidity, median (IQR)	0.194 (0.15–0.24)	0.171 (0.13–0.21)	<0.001	9.8 (8–12)	8.3 (7–11)	<0.001
Complication observed to expected ratio	1.17 ± 0.07	1.29 ± 0.06	0.63	1.60 ± 0.10	1.03 ± 0.03	0.06

ACS, American College of Surgeons; ER, enhanced recovery; IQR, interquartile range; SSI, surgical site infection.

academic medical centers, other multi-institutional efforts have been described previously.[28,29] The National Health Service, through the UK Department of Health Enhanced Recovery Partnership Programme, sought to expand ER across National Health Service hospitals in patients undergoing colorectal, musculoskeletal, gynecology, and urology procedures. This collaboration resulted in varying levels of compliance with ER elements and underlying trends toward shortened LOS. Similarly, the Agency for Healthcare Research and Quality Safety Program for Improving Surgical Care and Recovery is a collaborative program focused on enhancing the recovery of surgical patients.[29] The program was launched in 2017 and represents a partnership between the Johns Hopkins Medicine Armstrong Institute for Patient Safety and Quality and the ACS, using the Comprehensive Unit-Based Safety Program methodology to standardize the surgical process and improve outcomes. Finally, the Michigan Surgical Quality Collaborative has endorsed statewide adoption of ER principles in participating institutions, with 22% of hospitals demonstrating a fully implemented ER protocol.[30] However, clinical outcomes from the Agency for Healthcare Research and Quality Safety Program and the Michigan Surgical Quality Collaborative are not yet available.

The most important specific elements of a successful ER program have yet to be fully elucidated. Based on their

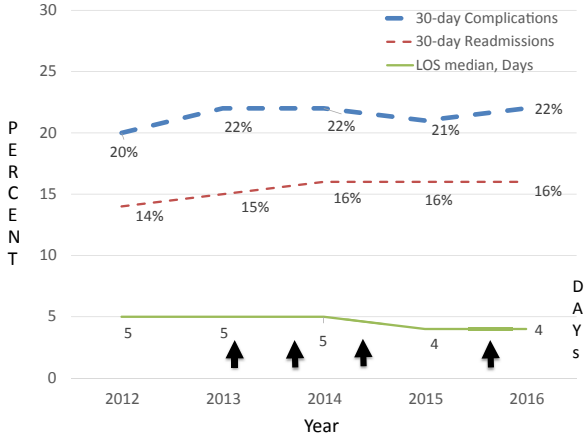

Figure 2. Postoperative complications and length of stay in Virginia Surgical Quality Collaborative (VSQC) open colectomy 2012 to 2016 pre- and post-enhanced recovery protocol implementation. Arrows indicate date of enhanced recovery implementation in VSQC hospitals. LOS, length of stay.

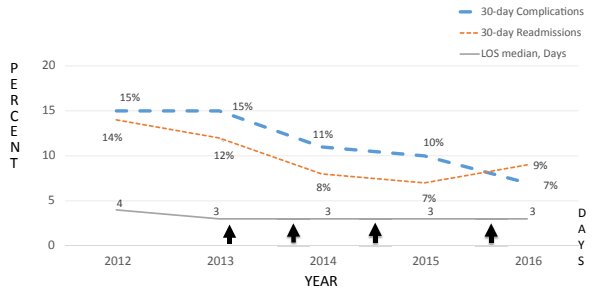

Figure 3. Postoperative complications and length of stay in Virginia Surgical Quality Collaborative (VSQC) laparosopic colectomy 2012 to 2016 pre- and post-enhanced recovery protocol implementation. Arrows indicate date of enhanced recovery implementation in VSQC hospitals. LOS, length of stay.

experience with the National Health Service Enhanced Recovery Partnership Programme, Simpson and colleagues[28] surmised that changes in processes resulting from standardization might be equally as important in quality improvement as any individual element of ER. It has been demonstrated that the key to successful change management within a complex organization relies on participation of front-line providers in protocol development to facilitate buy-in and compliance.[31] Recognizing that there is not a "one size fits all approach" to ER, we encouraged local adaption of the specific ER protocol elements at each institution, while assuring that each ER protocol followed the main tenets of ER. These basic ER philosophical principles were reinforced repeatedly during the collaborative discussions about the implementation process and likely contributed to the overall success of the program.

Improvements in outcomes were more evident in patients undergoing laparoscopic colectomy within the current study rather than open colon resection, although reductions in LOS and surgical site infections were seen in both patient groups. It is a common misconception that ER does not impact outcomes in patients undergoing minimally invasive procedures. We and others have previously demonstrated significant improvement in outcomes with implementation of ER in patients undergoing minimally invasive procedures.[18,21] In the current study, there was a significant shift in surgical approach over time, with significantly more patients undergoing laparoscopy in the later years of the study. As surgeons began incorporating laparoscopy into their practice, this likely selected out the most difficult cases in the open group, potentially confounding the results. This is further supported by finding that patients in the post-ER open group had significantly higher presence of inflammatory bowel disease, disseminated cancer, and steroid use—all factors associated with worse outcomes in patients undergoing colorectal operations.[32-35] Despite this, however, the predicted risk of morbidity in the post-ER group was lower than that of the pre-ER patients. It is not intuitively obvious how to reconcile the lower ACS NSQIP predicted morbidity scores over time in the setting of increasing proportions of other significant risk factors. The ACS NSQIP predicted morbidity is based on a statistical model generated from thousands of patients in the ACS NSQIP Participant Use File. Possible explanations include the impact of hospital expansion as more hospitals (with differing patient acuities) are incorporated into the NSQIP program. Additionally, this can also reflect the national impact of quality improvement efforts (such as ER) during the study period, with the subsequent reduction in predicted risk for similar patients based on globally improved outcomes.

There are significant limitations worthy of mention in the current study. Our cohort was limited to ACS NSQIP hospitals participating in the VSQC and represented 100% of potential VSQC participants (4 VSQC hospitals met study criteria and all participated in the study), but only 4% of all Virginia hospitals. The before and after study design prevents definitive attribution of improved outcomes to the quality improvement efforts of the VSQC, as association does not guarantee causation. As noted previously, staggering the start time of ER protocol implementation at study sites resulted in fewer post intervention cases for one institution in particular and this might have affected results. The staggered ER implementation also limited analysis options. More robust analysis (eg interrupted time series) would be possible with additional post-intervention data points. However, to the extent possible, we controlled for confounding variables in the logistic regression analysis. Additionally, although each site monitored compliance with implementation of their ER protocol, we were unable to track compliance data with individual ER

Table 4. Results from the Multivariable Logistic Regression Analysis of 30-Day Complications after Surgery for 2,438 Virginia Surgical Quality Collaborative Colectomy Procedures Performed from 2013 to 2016

Covariable, reference group	Odds ratio (95% CI)	p Value
Hypertension, non-hypertensive	1.31 (1.01−1.70)	0.046
ASA ≥3, ASA <3	1.61 (1.25−2.06)	<0.001
Current smoker, non-smoker	1.5 (1.1−2.00)	0.008
Laparoscopy, open	0.50 (0.40−0.64)	<0.001
ER protocol, pre-ER	0.70 (0.55−0.89)	0.003

Model variables included age (continuous), race (categorical), BMI (continuous), diabetes mellitus (categorical), smoking (categorical), hypertension (categorical), functional health status (categorical), ASA physical status classification (categorical), hospital (categorical), ER (categorical), and laparoscopy (categorical).
ASA, American Society of Anesthesiologists; ER, enhanced recovery.

elements for each of the participating institutions, given the heterogeneity between institutional protocols. Rather than enforcing a single protocol across all institutions, we recognized the importance of individuality in facilitating successful implementation. Finally, there are other important variables missing from this de-identified shared institutional database, such as hospital costs and data on opioid consumption—both important elements in ER pathways.

CONCLUSIONS

Implementation of ER across VSQC was associated with significant reductions in LOS and overall complications, particularly in patients undergoing laparoscopic colectomy. These data suggest that organizational collaboration can be efficacious and it is possible to implement ER across the continuum of care in multiple institutions and practice patterns.

Author Contributions

Study conception and design: Hedrick, Reines, Fogel, Posadas, Turrentine, RS Jones

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Analysis and interpretation of data: Hedrick Thiele, Hassinger

Drafting of manuscript: Hedrick, Hassinger

Critical revision: Turrentine, Thiele, Donovan, Reines, Damico, Fogel, RS Jones, Posadas, JE Jones

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eDocument 1.
ENHANCED RECOVERY PROTOCOLS ACROSS VIRGINIA SURGICAL QUALITY COLLABORATIVE SITES

ER Protocol, Hospital 1

- Preoperative
  - Preoperative analgesia before operative room entry; preferably 1 hour before
    - Celecoxib 400 mg po once
    - Acetaminophen 1,000 mg po once
    - Gabapentin 600 mg po once
- Intraoperative
  - Set-up of closing tray
  - Anesthesia management, medications, and fluid monitoring (EV1000 finger probe)
  - Opioids-anesthesia
    - Opioids IV at discretion of anesthesiologist supplemented with ketamine, ketorolac, or both
    - Postoperative nausea and vomiting prophylaxis; before incision closure (±30 minutes) anesthesia
    - Dexamethasone 4 mg IV once
    - Ondansetron 4 mg IV once
    - Before incision closure:
      - Liposomal bupivacaine (Exparel) 30 mL: administer as 6 injections (5 mL) to incision sites, operating room nursing
      - Acetaminophen 1000 mg IV over 15 minutes timing to be determined (if NSAIDs is contraindicated) anesthesia
      - Postoperative
  - No IV patient-controlled analgesia (PCA), acetaminophen and ketorolac scheduled together unless contraindication with NSAIDs
    - Oxycodone 5 mg po q4h as needed for pain score 4 to 6
    - Oxycodone 10 mg po q4h as needed for pain score 7 to 10
    - Acetaminophen 1,000 mg po q6h for patients with no or mild hepatic disease
    - Acetaminophen 1,000 mg po twice daily for patients with moderate hepatic disease (maximum acetaminophen should not exceed 4,000 mg/24 h from all sources)
    - Ketorolac 15 mg IV q6h for 4 doses (start no sooner than 6 hours after last intraoperative dose); then, ibuprofen 800 mg po q6h (start 6 hours after last ketorolac dose administered)
  - If patient unable to take NSAIDs:
    - Tramadol 100 mg po 4 times a day (start at 6:00 AM day after operation) for patients aged younger than 65 years and no history of renal impairment or hepatic disease
    - Tramadol 100 mg po twice daily (start at 6:00 AM day after operation) for patients aged 65 years and older creatinine clearance <30 mL/min or history of hepatic disease
  - Breakthrough pain (pain >7 more than 1 hour after receiving oxycodone)
    - Hydromorphone 0.4 mg IV once if patient did not receive intrathecal medications; may repeat once after 20 minutes if first dose ineffective
  - IV PCA
    - Hydromorphone PCA started only if continued pain despite 2 doses of IV hydromorphone; call surgeon for PCA order

ER Protocol, Hospital 2

- Preoperative
  - Patients to attend pre-habilitation class
  - Selective bowel preparation
  - If laparoscopic case, Entereg (alvimopan) 12 mg po to be started preoperatively when patient gets to post-anesthesia preparation area; open cases do not receive Entereg
    - Entereg is contraindicated in patients who have had narcotics for 7 or more days before operation
    - Celecoxib 400 mg po
    - Gabapentin 600 mg po
    - Sequential compression device (SCD) on patient connected to pump and pump on
- Intraoperative
  - Surgeon
    - Wound protector if open case, or in extraction site if laparoscopic
    - No nasogastric (NG) tube
  - Anesthesia
    - Goal-directed fluid therapy with protocol as per anesthesia
    - Open cases: thoracic epidural
      - Anesthesia will be responsible for monitoring effectiveness/complications while it is in
      - If patient refuses or is not a candidate, follow guidelines for laparoscopic case
    - Laparoscopic cases:
      - 1 dose spinal Duramorph (morphine sulfate) and combination Entereg and IV lidocaine

IV lidocaine started during case and continued for 24 hours (2 mg/min; 2 g in 500-mL bag at 30 mL/h)
Prophylactic treatment of nausea and vomiting with 2 drugs before end of case (Zofran [ondansetron] 4 mg IV and Phenergan [promethazine] 12.5 mg IV if aged younger 65 years, 6.25 mg if aged 65 years and older)
80% inspired oxygen (FiO_2)
Toradol (ketorolac) 30 mg IV, or 15 mg IV if aged older than 65 years or compromised renal function, before end of case (can be omitted if high-risk anastomosis)
Ofirmev (acetaminophen) 1 g IV before end of case (except in cirrhotics)
No intraoperative opioids, limit nitrous, limit inhalation agents
SCDs on patient connected to pump and pump on
Post-anesthesia care unit (PACU)
Continue 80% FiO2
Continue lidocaine drip, if present, at above rate
Lactated ringers (LR) at 40 mL/h
SCDs on patient connected to pump and pump on
Incentive spirometry therapy q1h
Postoperative
Management of epidurals
To be removed 8:00 am second morning after operation by nursing staff
Heparin 5,000 U subcutaneous bid to start night of operation for 2 doses
Skip 1 dose night before removal
Heparin or Lovenox restarted 2 hours after removal
If no epidural, the anticoagulation can be Lovenox as usual
Entereg in those who got it preoperatively, 12 mg po bid until first bowel movement or discharge, but not more than 15 doses (7 days). Entereg is contraindicated in patients who have had narcotics for 7 or more days before operation.
Toradol: 30 mg IV q6h for 48 hours if aged younger than 65 years and good renal function, 15 mg IV q6h for 48 hours if aged older than 65 years or compromised renal function
Ofirmev (acetaminophen) 1 g IV q6h for 24 hours (except in cirrhotics)
Then Tylenol 650 po q6h for 24 hours (except in cirrhotics)
Continue lidocaine drip (if present) at same rate for 24 hours
Early postoperative clear liquids po, noncarbonated (day of operation)
Increase to gastrointestinal light diet when tolerated po (usually by next morning)
IV LR at 40 mL/h
Discharge IV fluids once tolerating po well
Limit fluid boluses to only those with symptomatic hypotension or tachycardia
Add impact supplements tid once taking po well
Ambulation day of operation and tid
Foley out day 1 unless documented indication to remain. If patient cannot void, use intermittent catheter for 24 hours, based on bladder scan with >250 mL residual, before using another Foley
No NG tube
SCDs on patient connected to pump and pump on. SCDs must be on patient at all times except when patient is ambulating.

ER Protocol, Hospital 3

Day prior to operation
Regular diet until 6:00 PM
Bowel preparation (mechanical and oral antibiotics)
Chlorhexidine shower night before and morning of operation
Day of operation, preoperative holding area
Identify ER after operation patients and initiate protocol
Allow patients to have clears up until 2 hours before operation
Gatorade 20 oz, must be completed 2 hours before operation
Medications:
Alvimopan 12 mg po
Multimodal analgesia using:
Celecoxib 200 mg po (not given to patient with coronary artery disease)
Gabapentin 600 mg po
Acetaminophen 975 mg po
Intraoperative
Duramorph (100 μg) spinal preinduction; no intraoperative opioids without attending approval
Induction: propofol, ketamine 0.5 mg/kg, magnesium 30 mg/kg (over 10 minutes), dexamethasone 4 mg
IV analgesia: lidocaine 40 μg/kg/min (continued into PACU), ketamine 0.6 mg/kg/h (10 μg/kg/min, stop approximately 45 minutes before

- waking in laparoscopic, drop to 5 μg/kg/min for open cases)
- Goal-directed fluids guided by Pleth Variability Index: tidal volumes 6 to 8 mL/kg using 100% FiO_2

PACU
- Clears in PACU unless aspiration risk
- Stand patients for weight
- LR at 40 mL/h (unless patient aspiration risk and npo, then 75 mL/h)
- Continue lidocaine infusion

Postoperative care, surgical ward
- Diet: Clears begins night of operation, solid food POD 1
- Pain
  - 1 g IV acetaminophen 6 hours after initial dose and q6h
  - Lidocaine infusion (0.5 to 1.0 mg/min) until postoperative day (POD) 2
  - Oxycodone 5 mg po q 4 h pro re nata/as needed (PRN) mild pain, 10 mg q4h PRN moderate pain, oxycodone 15 mg po q4h PRN severe pain
  - Celecoxib 100 mg po bid in patients without coronary artery disease
  - No additional opioids, no PCA, no epidurals (without attending's approval)
- Activity: Ambulation begins night of operation, head of bed (HOB) at 30 degrees at all times
- Medications
  - Lovenox 40 mg to begin the morning of POD 1
  - Alvimopan 12 mg bid for 7 days
  - Magnesium oxide 400 mg po daily
- Fluids
  - LR at 40 mL/h for 24 hours

Discharge
- Medications: acetaminophen 1 g q8h for 1 week, oxycodone 5 mg q4h PRN
- Arrange for early follow-up in high-risk patients with surgeon or primary care provider
- Follow-up phone call within 48 hours of discharge

ER Protocol, Hospital 4

Clinic
- Educational materials

Preoperative
- Celecoxib
- Gabapentin
- Acetaminophen

Operative
- Goal-directed therapy
- Duramorph spinal
- Lidocaine infusion
- Continue to POD 2

Postoperative
- Clear liquids day of operation
- Ambulation night of operation
- HOB 30 degrees

Pain management
- Acetaminophen
- Celecoxib
- Oxycodone oral (PRN)
- Hydromophone oral (PRN)