JAMA Surgery | Original Investigation

Association of an Enhanced Recovery Pilot With Length of Stay in the National Surgical Quality Improvement Program

Julia R. Berian, MD, MS; Kristen A. Ban, MD, MS; Jason B. Liu, MD, MS; Christine L. Sullivan, MBA, MS; Clifford Y. Ko, MD, MS, MSHS; Julie K. M. Thacker, MD; Liane S. Feldman, MD

Invited Commentary

Supplemental content

IMPORTANCE Enhanced recovery protocols (ERPs) are standardized care plans of best practices that can decrease morbidity and length of stay (LOS). However, many hospitals need help with implementation. The Enhanced Recovery in National Surgical Quality Improvement Program (ERIN) pilot was designed to support ERP implementation.

OBJECTIVE To evaluate the association of the ERIN pilot with LOS after colectomy.

DESIGN, SETTING, AND PARTICIPANTS Using a difference-in-differences design, pilot LOS before and after ERP implementation was compared with matched controls in a hierarchical model, adjusting for case mix and random effects of hospitals and matched pairs. The setting was 15 hospitals of varied size and academic status from the National Surgical Quality Improvement Program. Preimplementation and postimplementation colectomy cases (July 1, 2013, to December 31, 2015) were collected using novel ERIN variables. Emergency and septic cases were excluded. A propensity score match identified a 2:1 control cohort of patients undergoing colectomy at non-ERIN hospitals.

INTERVENTIONS Pilot hospitals developed and implemented ERPs that included expert guidance, multidisciplinary teams, data audits, and opportunities for collaboration.

MAIN OUTCOMES AND MEASURES The primary outcome was LOS, and the secondary outcome was serious morbidity or mortality composite.

RESULTS There were 4975 colectomies performed by 15 ERIN pilot hospitals (3437 before implementation and 1538 after implementation) compared with a control cohort of 9950 colectomies (4726 before implementation and 5224 after implementation). The mean LOS decreased by 1.7 days in the pilot (6.9 [interquartile range (IQR), 4-8] days before implementation vs 5.2 [IQR, 3-6] days after implementation, *P* < .001) compared with 0.4 day in controls (6.4 [IQR, 4-7] days before implementation vs 6.0 [IQR, 3-7] days after implementation, *P* < .001). Readmission did not differ pre-post for the pilot or controls. Serious morbidity or mortality decreased for pilot participants (485 [14.1%] before implementation vs 162 [10.5%] after implementation, *P* < .001), with no difference in controls, and remained significant after risk adjustment (adjusted odds ratio, 0.76; 95% CI, 0.60-0.96). After adjusting for differences in case mix and for clustering in hospitals and matched pairs, the adjusted difference-in-differences model demonstrated a decrease in LOS by 1.1 days in the pilot over controls (*P* < .001).

CONCLUSIONS AND RELEVANCE Participating ERIN pilot hospitals achieved shorter LOS and decreased complications after elective colectomy, without increasing readmissions. The ability to implement ERPs across hospitals of varied size and resources is essential. Lessons from the ERIN pilot may inform efforts to scale this effective and evidence-based intervention.

JAMA Surg. doi:10.1001/jamasurg.2017.4906
Published online December 20, 2017.

Author Affiliations: Department of Surgery, University of Chicago, Chicago, Illinois (Berian, Liu); Division of Research and Optimal Patient Care, American College of Surgeons, Chicago, Illinois (Berian, Ban, Liu, Sullivan, Ko); Department of Surgery, Loyola University Medical Center, Maywood, Illinois (Ban); Department of Surgery, UCLA (University of California, Los Angeles) (Ko); Department of Surgery, Duke University, Durham, North Carolina (Thacker); Department of Surgery, McGill University, Montreal, Quebec, Canada (Feldman).

Corresponding Author: Julia R. Berian, MD, MS, Department of Surgery, University of Chicago, 5841 S Maryland Ave, Chicago, IL 60637 (julia.berian@uchospitals.edu).

Enhanced recovery protocols (ERPs) are standardized perioperative care plans that incorporate evidence-based best practices to improve surgical outcomes.[1,2] Interventions included in these multimodal pathways focus on minimizing physiologic stress, thereby promoting optimal and timely recovery. Protocol elements before, during, and after surgery aim to control pain, reduce gut dysfunction, and promote nutrition and physical activity.[3,4] There are many randomized trials, meta-analyses, and observational studies demonstrating the benefits of ERPs for reducing postoperative length of stay (LOS) and morbidity.[5,6]

Colectomy is one of the most common general surgery operations and accounts for a disproportionate share of postoperative morbidity and mortality.[7] Postoperative complications contribute significantly to future negative outcomes (eg, end-organ dysfunction, 30-day mortality, reoperation, and readmission)[8] and increased health care resource use.[9-11] Even among patients without complications, LOS varies widely.[12] Therefore, colectomy remains a priority for quality improvement activities. Implementation of ERPs can contribute to decreased postoperative complications, such as surgical site infection,[13] and can improve metrics of health care resource use, such as LOS and readmission, contributing to potential cost savings.[6,13-15] The results of recent studies[16,17] support the cost-effectiveness of ERP implementation, particularly with regard to decreasing LOS after colorectal surgery.

Despite the observed benefits, implementation of ERPs remains slow and challenging. A survey of the Society of American Gastrointestinal and Endoscopic Surgeons found that 30% of member respondents were unfamiliar with ERPs.[18] Hospitals and health care professionals often do not know where to begin in developing and implementing an ERP. Successful implementation often requires behavior change and coordination across multiple disciplines. Furthermore, health care in the United States is highly fragmented, and there is little opportunity for comparison across institutions. European collaborations have established large clinical data registries to support implementation of ERPs to monitor adherence with care processes and outcomes. However, no such registry was widely available in North America. To address this problem, the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) incorporated enhanced recovery process and outcome variables into the data platform and launched the Enhanced Recovery in National Surgical Quality Improvement Program (ERIN) pilot in 2014. The ERIN pilot was designed to facilitate implementation of ERPs by giving hospitals access to experts, resources, and data, while fostering cross-institution collaboration. The objective of this study was to evaluate the ERIN pilot for changes in LOS after colectomy compared with a cohort of control hospitals.

Key Points

Question How can the Enhanced Recovery in National Surgical Quality Improvement Program pilot help hospitals improve length of stay after colectomy?

Findings In a cohort study of 4975 colectomies performed by 15 pilot hospitals and 9950 control colectomies, key lessons in implementing the pilot were guidance from experts, engaged multidisciplinary team leadership, continuous data collection and auditing, and collaboration across institutions through monthly conference calls. Fifteen hospitals in the pilot decreased length of stay by 1.7 days (compared with 0.4 day among propensity-matched controls); after risk adjustment for patient characteristics, hospitals, and matched pairs, the adjusted decrease was significant at −1.1 days.

Meaning Lessons from the Enhanced Recovery in National Surgical Quality Improvement Program collaborative may benefit hospitals that want to implement enhanced recovery to improve length of stay.

Methods

ERIN Pilot Project

In 2014, the ACS NSQIP launched the ERIN pilot to support implementation of ERPs for colorectal surgery in NSQIP hospitals. Fifteen hospitals that were high outliers on LOS participated in the pilot: each formed a steering committee (surgery, anesthesia, and nursing leaders), developed a tailored ERP, implemented the protocol, and collected ERIN-specific data during surgery. Pilot hospitals gained access to experts with implementation experience, example materials (patient education materials and order sets), and opportunities for multi-institutional collaboration through conference calls and annual in-person workshops. Monthly conference calls provided a regular, structured mechanism for information exchange and real-time trouble-shooting opportunities among participating hospitals.

This retrospective cohort study was deemed nonhuman research and exempt from review board oversight by the Chesapeake Institutional Review Board. Informed consent was not applicable.

Protocol development was tailored by hospital according to the individual workflow. The ACS NSQIP provided 13 ERP-specific process variables (eTable in the Supplement). Hospitals were encouraged to use available ERIN variables; however, these components were not mandatory in their respective protocols. In-person workshops were conducted in quarters 2 and 5 of the pilot to review protocol development, implementation, adherence, and plans for sustainability. Timing of initial protocol implementation was at the discretion of each hospital and proceeded in a staggered fashion. The individualized implementation date was set as time 0 for each of the 15 pilot hospitals. The pilot start date of July 1, 2014, was set as time 0 for control hospitals.

Data Source and Study Population

The ACS NSQIP is a clinical data registry collecting perioperative data for the purpose of quality improvement.[19-21] Data are entered by trained surgical clinical reviewers and are audited for data accuracy.[22,23] Briefly, the ACS NSQIP comprises more than 200 data points, including preoperative patient demographics, comorbidities, laboratory values, and postoperative surgical complications for 30 days after surgery.

To evaluate the ERIN pilot, we compared colectomy outcomes before and after ERP implementation. Cases performed at pilot hospitals from January 1, 2013, until the hospital-specific implementation date comprised the preimplementation pilot cohort. There were 4318 colectomy cases eligible for inclusion across the 15 pilot hospitals. Exclusion criteria were emergency cases (624 [14.5%]), American Society of Anesthesiologists (ASA) class 5 (0 cases), and preoperative systemic inflammatory response syndrome, sepsis, or septic shock (257 [6.0%]). The final preimplementation cohort for pilot hospitals was 3437. The postimplementation pilot cohort included colectomy cases performed at pilot hospitals from the hospital-specific implementation date until December 31, 2015, with complete ERIN data entered (regardless of compliance level). There were 1666 postimplementation ERIN colectomy cases across the 15 pilot hospitals. After excluding emergency cases (81 [4.9%]), ASA class 5 (1 [0.1%]), and preoperative systemic inflammatory response syndrome, sepsis, or septic shock (46 [2.8%]), the postimplementation cohort for pilot hospitals was 1538.

To evaluate the association of ERIN participation with LOS, while accounting for temporal trends, we identified colectomy cases derived from the ACS NSQIP data from January 1, 2013, to December 31, 2015, in non-ERIN hospitals, applying the same exclusion criteria. Cases from nonpilot hospitals using the ERIN variables outside of the pilot were not eligible as controls. There were 351 hospitals and 50 126 cases eligible for the propensity score match into the control cohort.

Data from the 2014 American Hospital Association Annual Survey were merged with the ACS NSQIP data to capture hospital-level characteristics (total number of licensed hospital beds and teaching affiliation). Teaching hospitals were those designated as "major" by the Council of Teaching Hospitals and Health Systems or as "minor," approved to participate in training by the Accreditation Council for Graduate Medical Education or the American Osteopathic Association or those with medical school affiliation reported to the American Medical Association.

Statistical Analysis

Using a pre-post difference-in-differences design, we compared changes from baseline in postoperative LOS among ERIN colectomy cases with propensity-matched controls. A propensity score match was performed using a greedy 2:1 algorithm, with each colectomy case from pilot hospitals matched to 2 control cases from non-ERIN hospitals based on the year of the operation, hospital characteristics (total number of hospital beds and academic teaching status), and patient characteristics (age, sex, race, functional status before surgery, and American Society of Anesthesiologists [ASA] class). Propensity score match balance was assessed graphically comparing standardized differences in the means of matched variables before and after the match[24] using a threshold of 0.1 to define match success.[25,26] Standardized differences after the match appropriately fell within the threshold (eFigure 1 in the Supplement). There were parallel trends in preimplementation LOS: controls demonstrated a slope of −0.095 (95% CI, −0.193 to 0.003), while pilot sites demonstrated a slope of −0.039 (95% CI, −0.110 to 0.045).

Bivariate analyses compared preimplementation and postimplementation cohorts for pilot and control hospitals using *t* test, Wilcoxon rank sum test, Pearson product moment correlation χ^2 test, and Fisher exact test for continuous and categorical variables as appropriate. Two-sided analyses used $P < .05$ for statistical significance. Patient characteristics available for risk adjustment were the following: sex, race, Hispanic ethnicity, body mass index, smoking status, functional status before surgery, diabetes, unintentional weight loss, chronic corticosteroid use, disseminated cancer, hypertension requiring medication, history of congestive heart failure, history of chronic obstructive pulmonary disease, bleeding disorder, ASA class, dyspnea, ascites, preoperative renal failure, and dialysis.

Risk adjustment factors associated with LOS were evaluated in a generalized linear model with stepwise forward selection ($P < .05$ for entry). To provide a risk-adjusted estimate of the association of ERP implementation in pilot hospitals with LOS, a hierarchical linear regression model using gaussian distribution for LOS was then constructed, controlling for the previously selected patient-level risk factors, adjusting for the hospital and matched pairs as random effects, and evaluating the interaction between pilot participation and the pre-post indicator. The subsequent coefficient for the interaction term represents the risk-adjusted difference-in-differences estimate of the decrease in LOS associated with ERIN implementation at pilot sites.

The secondary outcome, serious morbidity or mortality, was first evaluated using a multivariable logistic regression with forward selection ($P < .05$ for entry). Selected factors were entered into a hierarchical logistic regression model of the binary outcome of serious morbidity or mortality, adjusting for the hospital and matched pairs as random effects, and evaluating the interaction between pilot participation and the pre-post indicator. The interaction coefficient was exponentiated to identify the odds ratio and 95% CI. All analyses were conducted using SAS statistical software (version 9.4; SAS Institute Inc).

Results

There were 3437 colectomies at the 15 ERIN pilot hospitals before ERP implementation and 1538 after implementation (**Table 1**). Compared with before implementation, there were fewer black or African American patients after implementation (378 [11.0%] vs 103 [6.7%], $P < .001$), fewer patients with partial or total functional dependence (97 [2.8%] vs 27 [1.8%], $P = .03$), and fewer patients with disseminated cancer (276 [8.0%] vs 88 [5.7%], $P = .004$). The control cohort also differed between the preimplementation and postimplementation periods in black or African American race (517 [10.9%] vs 462 [8.8%], $P < .001$) and in partially or totally dependent functional status before surgery (161 [3.4%] vs 130 [2.5%], $P = .007$).

Of the 15 pilot hospitals, 10 (66.7%) were major teaching hospitals, treating 3877 patients (77.9%) (**Table 2**). The matched patients came from 189 hospitals, of which 90 (47.6%) were major teaching hospitals, treating 7936 patients (79.8%).

Table 1. Patient Characteristics

Variable	Preimplementation Pilot (n = 3437)	Postimplementation Pilot (n = 1538)	*P* Value	Preimplementation Control (n = 4726)	Postimplementation Control (n = 5224)	*P* Value
Age, mean (SD), y	61.7 (15.3)	61.4 (14.9)	.03	61.8 (15.4)	61.2 (15.5)	.49
Female, No. (%)	1762 (51.3)	772 (50.2)	.49	2397 (50.7)	2609 (49.9)	.44
Race/ethnicity, No. (%)						
White	2435 (70.8)	1029 (66.9)	<.001	3430 (72.6)	3744 (71.7)	<.001
Black or African American	378 (11.0)	103 (6.7)		517 (10.9)	462 (8.8)	
Other or unknown	624 (18.2)	406 (26.4)		779 (16.5)	1018 (19.5)	
Body mass index, No. (%)						
Normal or underweight	1097 (31.9)	487 (31.7)	.65	1589 (33.6)	1784 (34.2)	.31
Overweight	1118 (32.5)	520 (33.8)		1653 (35.0)	1752 (33.5)	
Obese, class 1-3	1222 (35.6)	531 (34.5)		1484 (31.4)	1688 (32.3)	
Active smoking status, No. (%)	613 (17.8)	236 (15.3)	.03	748 (15.8)	791 (15.1)	.34
Functional status before surgery, No. (%)						
Independent	3340 (97.2)	1511 (98.2)	.03	4565 (96.6)	5094 (97.5)	.007
Partially or totally dependent	97 (2.8)	27 (1.8)		161 (3.4)	130 (2.5)	
Diabetes, No. (%)	517 (15.0)	204 (13.3)	.11	654 (13.8)	742 (14.2)	.60
Unintentional weight loss, No. (%)	180 (5.2)	100 (6.5)	.08	194 (4.1)	249 (4.8)	.12
Chronic corticosteroid use, No. (%)	328 (9.5)	148 (9.6)	.92	433 (9.2)	527 (10.1)	.13
Disseminated cancer, No. (%)	276 (8.0)	88 (5.7)	.004	252 (5.3)	317 (6.1)	.12
Hypertension requiring medication, No. (%)	1664 (48.4)	685 (44.5)	.01	2246 (47.5)	2432 (46.6)	.33
History of congestive heart failure, No. (%)	38 (1.1)	13 (0.8)	.45	36 (0.8)	59 (1.1)	.06
History of chronic obstructive pulmonary disease, No. (%)	169 (4.9)	60 (3.9)	.12	203 (4.3)	207 (4.0)	.42
Bleeding disorder, No. (%)	145 (4.2)	44 (2.9)	.02	145 (3.1)	163 (3.1)	.91
ASA class, No. (%)						
1, No disturbance	92 (2.7)	43 (2.8)	.24	124 (2.6)	141 (2.7)	.33
2, Mild disturbance	1651 (48.0)	780 (50.7)		2289 (48.4)	2519 (48.2)	
3, Severe disturbance	1564 (45.5)	668 (43.4)		2129 (45.0)	2395 (45.8)	
4, Life threatening	130 (3.8)	47 (3.1)		184 (3.9)	169 (3.2)	

Abbreviation: ASA, American Society of Anesthesiologists.

Table 2. Hospital Characteristics in Pilot and Control Cohorts

Variable	No. (%)			
	Pilot Hospitals (n = 15)	Pilot Patients (n = 4975)	Control Hospitals (n = 189)	Control Patients (n = 9950)
Teaching affiliation				
Major	10 (66.7)	3877 (77.9)	90 (47.6)	7936 (79.8)
Minor	5 (33.3)	1098 (22.1)	99 (52.4)	2014 (20.2)
Hospital size, total beds				
<200	2 (13.3)	216 (4.3)	26 (13.8)	290 (2.9)
200-399	3 (20.0)	527 (10.6)	63 (33.3)	1408 (14.2)
400-599	4 (26.7)	1478 (29.7)	53 (28.0)	2366 (23.8)
600-799	2 (13.3)	748 (15.0)	30 (15.9)	2290 (23.0)
≥800	4 (26.7)	2006 (40.3)	17 (9.0)	3596 (36.1)

Pilot and control hospitals varied in size. Two hospitals (13.3%) with less than 200 beds accounted for 216 patients (4.3%), and 4 hospitals (26.7%) with at least 800 beds accounted for 2006 patients (40.3%). There were 26 hospitals (13.8%) with less than 200 beds, accounting for 290 patients (2.9%), and 17 hospitals (9.0%) with at least 800 beds, accounting for 3596 patients (36.1%).

Setting the implementation date as time 0 for each ERIN hospital, adherence to process elements was tracked over time (eFigure 2 in the Supplement). Adherence to preoperative counseling improved from 51.7% (208 of 402) in quarter 1 after implementation to 82.7% (81 of 98) in quarter 6, and shortened fluid fast improved from 41.8% (168 of 402) to 63.3% (62 of 98). Adherence to maintenance of normothermia, multi-

Table 3. Postoperative Outcomes

Variable	Preimplementation Pilot (n = 3437)	Postimplementation Pilot (n = 1538)	*P* Value	Preimplementation Control (n = 4726)	Postimplementation Control (n = 5224)	*P* Value
Length of stay, mean (SD), d	6.9 (6.4)	5.2 (4.1)	<.001	6.4 (6.0)	6.0 (5.6)	<.001
Length of stay, median (interquartile range), d	5.0 (4-8)	4.0 (3-6)	NA	5.0 (4-7)	5.0 (3-7)	NA
Readmission, No. (%)	352 (10.2)	148 (9.6)	.54	466 (9.9)	488 (9.3)	.38
Serious morbidity or mortality composite, No. (%)	485 (14.1)	162 (10.5)	<.001	608 (12.9)	659 (12.6)	.71

Abbreviation: NA, not applicable.

modal management of pain, and antiemetic prophylaxis was consistently above 90% throughout the pilot period. Postoperative mobilization increased modestly but then declined (eg, mobilization on postoperative day [POD] 0 began at 66.7% [268 of 402] in quarter 1, rose to 85.9% [226 of 263] in quarter 3, and then fell to 61.2% [60 of 98] in quarter 6). Clear liquid diet on POD 0 improved from 73.4% (295 of 402) in quarter 1 to 91.8% (90 of 98) in quarter 6, while solid diet on POD 1 improved from 44.8% (180 of 402) to 65.3% (64 of 98). Foley catheter discontinuation on POD 1 was consistently greater than 80%, while discontinuation of intravenous fluid on POD 1 was consistently less than 50% throughout the pilot.

Before ERIN, the mean LOS for the pilot cohort was 6.9 (median, 5.0; interquartile range [IQR], 4-8) days (**Table 3**). After implementation, the mean LOS was 5.2 (median, 4.0; IQR, 3-6) days ($P < .001$). Among controls, the mean LOS was 6.4 (median, 5.0; IQR, 4-7) days before implementation and 6.0 (median, 5.0; IQR, 3-7) days after implementation ($P < .001$). The decrease in LOS between the preimplementation and postimplementation periods was greater in the pilot cohort than controls (**Figure**). The unadjusted difference-in-differences in LOS was −1.3 days. In a hierarchical linear model adjusted for patient risk factors (sex, functional status before surgery, unintentional weight loss, chronic corticosteroid use, disseminated cancer, history of congestive heart failure, history of chronic obstructive pulmonary disease, bleeding disorder, ASA class, ascites, and renal failure) and clustering within hospitals and matched pairs, the pilot remained significant at an adjusted difference-in-differences (SE) of −1.1 (0.2) days ($P < .001$).

There was no significant difference in unadjusted rates of readmission across pre-post periods for either the pilot cohort or controls. Unadjusted rates of serious morbidity or mortality decreased for the pilot cohort (485 [14.1%] before implementation vs 162 [10.5%] after implementation, $P < .001$) (Table 3). There was no difference in serious morbidity or mortality in controls. In a hierarchical model adjusted for patient characteristics (age, sex, Hispanic ethnicity, smoking status, functional status before surgery, unintentional weight loss, chronic corticosteroid use, disseminated cancer, hypertension requiring medication, history of congestive heart failure, history of chronic obstructive pulmonary disease, bleeding disorder, and ASA class) and controlling for clustering within hospitals and matched pairs, cases from pilot sites after implementation were significantly less likely to have serious morbidity or mortality (adjusted odds ratio, 0.76; 95% CI, 0.60-0.96).

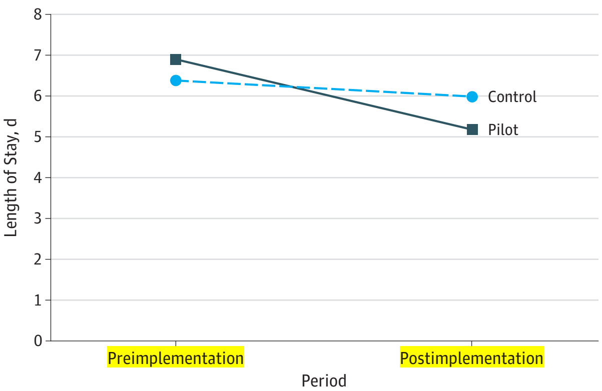
Discussion

The ERIN pilot harnessed expert guidance, provided a basic structure for team leadership, facilitated data collection with 13 specific enhanced recovery processes, and encouraged collaboration through regularly scheduled conference calls. Through the ERIN pilot, 15 hospitals successfully decreased LOS by 1.7 days among patients undergoing colectomy, which was significant compared with the 0.4-day decrease observed in a propensity-matched cohort of patients undergoing colectomy at control hospitals. After risk adjustment, accounting for patient risk factors, hospitals, and matched pairs, the ERIN pilot experience was significant, with average LOS decreased by an additional 1.1 days beyond temporal trends. Given the range of small to large pilot hospitals with varied resources, the pilot experience may inform enhanced recovery at other hospitals. Future collaboratives may consider drawing on lessons of the ERIN pilot—external expertise, team leadership, data audits, and collaboration—to facilitate enhanced recovery implementation.

Given variable implementation and adherence,[27] there is a need to better understand barriers and facilitators for ERPs. Effective implementation may require care reorganization, including building interdisciplinary teams, counseling patients on anticipated recovery, and ensuring coordination across siloed disciplines.[28] Stakeholder interviews in an Australian hospital found barriers related to patients, staff, resources, and the overall practice workflow.[29] Semistructured interviews across 7 University of Toronto–affiliated Canadian hospitals identified lack of support staff, poor communication, and a need to appropriately set patient expectations as barriers to ERP implementation.[30] Furthermore, many physicians cited their own resistance to change (or resistance among others) as a major barrier.[30]

Enhanced recovery implementation poses challenges associated with culture change, staff limitations, and financial resources. Because many ERP studies are conducted in the setting of large tertiary academic hospitals, smaller hospitals may be concerned about feasibility. However, key enablers for success do not depend on hospital size or teaching status: an engaged champion who believes in the value of the ERP may succeed by establishing a good fit between the champion and the team, engaging stakeholders at all levels, and normalizing the ERP as part of expected routine.[31] Regardless of resource limitations, small hospitals may have the advantage of decreased

Figure. Mean Length of Stay After Colectomy for the Enhanced Recovery in National Surgical Quality Improvement Program Pilot Compared With Controls



The mean (SD) unadjusted length of stay in the pilot cohort was 6.9 (6.4) days before implementation and 5.2 (4.1) days after implementation, or a decrease of 1.7 days. The mean (SD) unadjusted length of stay in the control cohort was 6.4 (6.0) days before implementation and 6.0 (5.6) after implementation, or a decrease of 0.4 day. This amounts to a 1.3-day difference-in-differences length of stay for the association of pilot participation before vs after implementation. In a multivariable hierarchical generalized linear model, the association of pilot participation remained significant at a difference-in-differences (SE) of −1.1 (0.2) days (P < .001) after adjusting for patient risk factors, hospitals, and matched controls.

bureaucracy and improved communication and collaboration across disciplines. The ERIN pilot study included hospitals of various sizes, indicating that both small and large hospitals can successfully decrease LOS with implementation of an ERP.

The ERIN pilot sought to ease the learning curve by providing hospitals access to experts in the field, a structure for team leadership, a mechanism to audit adherence with care processes and outcomes, and a platform for collaboration across institutions (**Table 4**). A systematic review of regional collaboration identified key factors for quality improvement success, including the ability to establish trust and share best practices among a network of peers, availability of accurate and relevant data, strong institutional support and clinical leadership, and resources and infrastructure for quality improvement initiatives.[32] With regard to enhanced recovery, collaboratives should allow the flexibility for participating hospitals to develop a tailored ERP paired with an implementation strategy, engage local multidisciplinary champions to facilitate collaboration and communication, provide patient educational materials, and establish an audit and feedback mechanisms.[33]

Data auditing is consistently identified as a key facilitator for both implementation and sustainability.[33,34] Protocol adherence may fluctuate over time,[35,36] and lax compliance can threaten early gains. Compliance with postoperative protocol elements is consistently lower than preoperative or intraoperative elements[27,37] and may decline with time.[35] In the context of symptoms or complications, nonadherence may be unavoidable (eg, nausea and vomiting requiring cessation of oral intake). However, one study[38] found that 20% or more of protocol deviations may have no medically justified rationale. Compliance within the ERIN pilot was lowest for minimizing intravenous fluids, consistent with previously observed variability in fluid management strategies in which high volume was associated with LOS, cost, and ileus.[39]

Table 4. National Surgical Quality Improvement Program (ERIN) Pilot Tools for Enhanced Recovery Protocol (ERP) Implementation

Pilot Activity	Individual Hospital Activities
Year 1, Quarter 1	
In-person kickoff session	
Goals: to introduce ERP evidence; to initiate the ERIN pilot	Create ERIN steering committee; official participation agreements
Monthly conference calls	
Discussion of culture change, building steering committees; preparation for in-person workshop	Bring team updates to each call; ask questions
Year 1, Quarter 2	
In-person workshop	
Activity: build process map for ERP at each pilot site	Pilot sites sent team representatives to workshop, prepared to build process map
Monthly conference calls	
Distribution of example materials; focus on the overall protocol elements: tips and pitfalls for designing one's protocol	Bring site updates to each call; ask questions
Year 1, Quarter 3	
Monthly conference calls	
Discussion of preoperative protocol elements (patient education, preoperative clear liquids, multimodal pain management); in-depth review of preoperative variables for data collection; iterative discussion of implementation and rollout plans	Bring site updates to each call; focus on implementation rollout
Year 1, Quarter 4	
Monthly conference calls	
Discussion of intraoperative protocol elements (normothermia, goal-directed fluid therapy, multimodal antiemetics); in-depth review of intraoperative variables for data collection; iterative discussion of implementation and rollout plans for those not yet implementing protocol	Bring site updates to each call; trouble-shooting difficulties as they arise
Year 2, Quarter 1	
In-person meeting	
Overview of data completion with data audit; site presentations; in-depth discussion of variables, including areas of clarification	Each site prepared 10-min presentations on preliminary data and outcomes from ERP implementation
Year 2, Quarter 2	
Quarterly conference calls	
Review of year 1 data, noting areas of poor compliance and plan for improvement	Pilot sites give feedback on current data; make plan for compliance improvement
Year 2, Quarter 3	
Quarterly conference call	
Data update on year 2 quarters 1-2 data; webinar focused on how to audit adherence and sustain protocol; survey issued to plan for future meetings and calls	Pilot sites participate in how-to webinar; ask questions; complete survey for future pilot planning
Year 2, Quarter 4	
In-person summary session	
Final review of pilot data; presentation to update sites on recent ERP literature	Each site participated in breakout sessions to provide feedback to the pilot and directions for next steps

Strengths and Limitations

A strength of this study is the inclusion of small and large institutions. Drawing on the ACS NSQIP platform, the ERIN pilot was able to accrue sufficient numbers for a meaningful analysis. Pilot clinical reviewers were specifically trained on the definitions of adherence with the ERIN variables. Furthermore, using a difference-in-differences analysis with a cohort of patients undergoing colectomy as a comparator group, rather than relying on historical controls or patients undergoing a different operation, takes into account secular trends in outcomes.

However, this study is not without limitations. First, the ACS NSQIP includes hospitals actively engaged in quality efforts, and pilot participation was voluntary, limiting generalizability. Second, there are no historical data on ERIN process elements; therefore, changes in adherence cannot be tracked from before to after implementation. Third, pilot hospitals controlled the development and implementation of the ERP in accordance with local workflow. None of the protocol elements were required, and there is likely substantial variation in the full protocols implemented across pilot hospitals. Fourth, preimplementation and postimplementation patient cohorts differed, possibly due to selection of lower-risk patients for participation in ERPs. We have attempted to adjust for this difference with propensity matching and multivariable risk adjustment. Fifth, to provide flexible protocol elements, the ERIN variables may lack granularity. Hospitals examining ERP components in detail (eg, distance or duration of mobilization) may gain insight to improve implementation or sustainability of the ERPs.

Motivated hospitals may achieve success independently; however, it remains unclear who will lead implementation and dissemination of enhanced recovery in the future. The ACS, the Johns Hopkins Medicine Armstrong Institute for Patient Safety and Quality, and the Agency for Healthcare Research and Quality have recently launched the "Improving Surgical Care and Recovery" program to provide more than 750 hospitals with tools, experts, and other resources for implementation of ERPs. The program is one opportunity for hospitals seeking implementation guidance. Whichever implementation strategy is selected, we strongly believe that surgeon engagement and leadership in such initiatives are critical to sustained success.

Conclusions

The ERIN pilot successfully decreased LOS compared with a control cohort of patients undergoing colectomy. Key lessons in implementing the ERIN pilot were external expertise, team leadership, data audits, and cross-institutional collaboration. The pilot may serve to inform future implementation efforts across hospitals varied in size, location, and resource availability.

ARTICLE INFORMATION

Accepted for Publication: August 25, 2017.

Published Online: December 20, 2017. doi:10.1001/jamasurg.2017.4906

Author Contributions: Dr Berian had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Berian, Ban, Liu, Ko, Thacker, Feldman.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Berian, Thacker.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Berian, Liu, Sullivan.
Administrative, technical, or material support: Berian.
Study supervision: Ko, Thacker, Feldman.

Conflict of Interest Disclosures: Dr Berian reported receiving salary support from The John A. Hartford Foundation. Dr Ban reported receiving salary support from the Agency for Healthcare Research and Quality. Dr Ko reported being coprincipal investigator for the grants from The John A. Hartford Foundation and the Agency for Healthcare Research and Quality. Dr Thacker reported having financial relationships with the following entities: Merck, Edwards Lifesciences, Cheetah Medical, Covidien-Medtronic, Premier, and Abbott Nutritional. Dr Feldman reported receiving an investigator-initiated research grant from Merck. No other disclosures were reported.

Meeting Presentation: This work was presented in part at the American Society of Colon and Rectal Surgeons 2017 Annual Scientific and Tripartite Meeting; June 11, 2017; Seattle, Washington.

Additional Contributions: Jennifer L. Paruch, MD, MS (North Shore Medical Group, Evanston, Illinois) and Sanjay Mohanty, MD, MS (Henry Ford Health System, Detroit, Michigan) assisted in organizing the pilot and drafting the variables. No compensation was received. We acknowledge the Enhanced Recovery in National Surgical Quality Improvement Program (ERIN) pilot hospitals, particularly their respective data abstractors and clinical leaders, for their work in this collaborative.

REFERENCES

1. Scott MJ, Baldini G, Fearon KC, et al. Enhanced Recovery After Surgery (ERAS) for gastrointestinal surgery, part 1: pathophysiological considerations. *Acta Anaesthesiol Scand*. 2015;59(10):1212-1231.

2. Feldheiser A, Aziz O, Baldini G, et al. Enhanced Recovery After Surgery (ERAS) for gastrointestinal surgery, part 2: consensus statement for anaesthesia practice. *Acta Anaesthesiol Scand*. 2016;60(3):289-334.

3. Gustafsson UO, Scott MJ, Schwenk W, et al; Enhanced Recovery After Surgery (ERAS) Society, for Perioperative Care; European Society for Clinical Nutrition and Metabolism (ESPEN); International Association for Surgical Metabolism and Nutrition (IASMEN). Guidelines for perioperative care in elective colonic surgery: Enhanced Recovery After Surgery (ERAS) Society recommendations. *World J Surg*. 2013;37(2):259-284.

4. Nygren J, Thacker J, Carli F, et al; Enhanced Recovery After Surgery (ERAS) Society, for Perioperative Care; European Society for Clinical Nutrition and Metabolism (ESPEN); International Association for Surgical Metabolism and Nutrition (IASMEN). Guidelines for perioperative care in elective rectal/pelvic surgery: Enhanced Recovery After Surgery (ERAS) Society recommendations. *World J Surg*. 2013;37(2):285-305.

5. Lv L, Shao YF, Zhou YB. The Enhanced Recovery After Surgery (ERAS) pathway for patients undergoing colorectal surgery: an update of meta-analysis of randomized controlled trials. *Int J Colorectal Dis*. 2012;27(12):1549-1554.

6. Adamina M, Kehlet H, Tomlinson GA, Senagore AJ, Delaney CP. Enhanced recovery pathways optimize health outcomes and resource utilization: a meta-analysis of randomized controlled trials in colorectal surgery. *Surgery*. 2011;149(6):830-840.

7. Schilling PL, Dimick JB, Birkmeyer JD. Prioritizing quality improvement in general surgery. *J Am Coll Surg*. 2008;207(5):698-704.

8. Scarborough JE, Schumacher J, Kent KC, Heise CP, Greenberg CC. Associations of specific postoperative complications with outcomes after elective colon resection: a procedure-targeted approach toward surgical quality improvement. *JAMA Surg*. 2017;152(2):e164681.

9. Vonlanthen R, Slankamenac K, Breitenstein S, et al. The impact of complications on costs of major surgical procedures: a cost analysis of 1200 patients. *Ann Surg*. 2011;254(6):907-913.

10. Zogg CK, Najjar P, Diaz AJ, et al. Rethinking priorities: cost of complications after elective colectomy. *Ann Surg*. 2016;264(2):312-322.

11. Liu JB, Berian JR, Chen S, et al. Postoperative complications and hospital payment: implications for achieving value. *J Am Coll Surg*. 2017;224(5):779-786.e2.

12. Cohen ME, Bilimoria KY, Ko CY, Richards K, Hall BL. Variability in length of stay after colorectal surgery: assessment of 182 hospitals in the National

Surgical Quality Improvement Program. *Ann Surg*. 2009;250(6):901-907.

13. Keenan JE, Speicher PJ, Nussbaum DP, et al. Improving outcomes in colorectal surgery by sequential implementation of multiple standardized care programs. *J Am Coll Surg*. 2015;221(2):404-414.e1.

14. Lawrence JK, Keller DS, Samia H, et al. Discharge within 24 to 72 hours of colorectal surgery is associated with low readmission rates when using enhanced recovery pathways. *J Am Coll Surg*. 2013;216(3):390-394.

15. Geltzeiler CB, Rotramel A, Wilson C, Deng L, Whiteford MH, Frankhouse J. Prospective study of colorectal Enhanced Recovery After Surgery in a community hospital. *JAMA Surg*. 2014;149(9):955-961.

16. Lee L, Li C, Landry T, et al. A systematic review of economic evaluations of enhanced recovery pathways for colorectal surgery. *Ann Surg*. 2014;259(4):670-676.

17. Lee L, Mata J, Ghitulescu GA, et al. Cost-effectiveness of enhanced recovery versus conventional perioperative management for colorectal surgery. *Ann Surg*. 2015;262(6):1026-1033.

18. Keller DS, Delaney CP, Senagore AJ, Feldman LS; SAGES SMART Task Force. Uptake of enhanced recovery practices by SAGES members: a survey. *Surg Endosc*. 2016.

19. Khuri SF, Henderson WG, Daley J, et al; Principal Investigators of the Patient Safety in Surgery Study. Successful implementation of the Department of Veterans Affairs' National Surgical Quality Improvement Program in the private sector: the Patient Safety in Surgery Study. *Ann Surg*. 2008;248(2):329-336.

20. Hall BL, Hamilton BH, Richards K, Bilimoria KY, Cohen ME, Ko CY. Does surgical quality improve in the American College of Surgeons National Surgical Quality Improvement Program? an evaluation of all participating hospitals. *Ann Surg*. 2009;250(3):363-376.

21. Cohen ME, Liu Y, Ko CY, Hall BL. Improved surgical outcomes for ACS NSQIP hospitals over time: evaluation of hospital cohorts with up to 8 years of participation. *Ann Surg*. 2016;263(2):267-273.

22. Shiloach M, Frencher SK Jr, Steeger JE, et al. Toward robust information: data quality and inter-rater reliability in the American College of Surgeons National Surgical Quality Improvement Program. *J Am Coll Surg*. 2010;210(1):6-16.

23. Cohen ME, Ko CY, Bilimoria KY, et al. Optimizing ACS NSQIP modeling for evaluation of surgical quality and risk: patient risk adjustment, procedure mix adjustment, shrinkage adjustment, and surgical focus. *J Am Coll Surg*. 2013;217(2):336-46.e1.

24. Stuart EA. Matching methods for causal inference: A review and a look forward. *Stat Sci*. 2010;25(1):1-21.

25. Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. *Stat Med*. 2009;28(25):3083-3107.

26. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behav Res*. 2011;46(3):399-424.

27. Ahmed J, Khan S, Lim M, Chandrasekaran TV, MacFie J. Enhanced Recovery After Surgery protocols: compliance and variations in practice during routine colorectal surgery. *Colorectal Dis*. 2012;14(9):1045-1051.

28. Kahokehr A, Sammour T, Zargar-Shoshtari K, Thompson L, Hill AG. Implementation of ERAS and how to overcome the barriers. *Int J Surg*. 2009;7(1):16-19.

29. Lyon A, Solomon MJ, Harrison JD. A qualitative study assessing the barriers to implementation of Enhanced Recovery After Surgery. *World J Surg*. 2014;38(6):1374-1380.

30. Pearsall EA, Meghji Z, Pitzul KB, et al. A qualitative study to understand the barriers and enablers in implementing an Enhanced Recovery After Surgery program. *Ann Surg*. 2015;261(1):92-96.

31. Gotlib Conn L, McKenzie M, Pearsall EA, McLeod RS. Successful implementation of an Enhanced Recovery After Surgery programme for elective colorectal surgery: a process evaluation of champions' experiences. *Implement Sci*. 2015;10:99.

32. Fung-Kee-Fung M, Watters J, Crossley C, et al. Regional collaborations as a tool for quality improvements in surgery: a systematic review of the literature. *Ann Surg*. 2009;249(4):565-572.

33. McLeod RS, Aarts MA, Chung F, et al. Development of an Enhanced Recovery After Surgery guideline and implementation strategy based on the Knowledge-to-action cycle. *Ann Surg*. 2015;262(6):1016-1025.

34. Ament SM, Gillissen F, Moser A, et al. Identification of promising strategies to sustain improvements in hospital practice: a qualitative case study. *BMC Health Serv Res*. 2014;14:641.

35. Gillissen F, Ament SM, Maessen JM, et al. Sustainability of an Enhanced Recovery After Surgery program (ERAS) in colonic surgery. *World J Surg*. 2015;39(2):526-533.

36. Cakir H, van Stijn MF, Lopes Cardozo AM, et al. Adherence to Enhanced Recovery After Surgery and length of stay after colonic resection. *Colorectal Dis*. 2013;15(8):1019-1025.

37. Messenger DE, Curtis NJ, Jones A, Jones EL, Smart NJ, Francis NK. Factors predicting outcome from enhanced recovery programmes in laparoscopic colorectal surgery: a systematic review. *Surg Endosc*. 2017;31(5):2050-2071.

38. Roulin D, Muradbegovic M, Addor V, Blanc C, Demartines N, Hübner M. Enhanced recovery after elective colorectal surgery: reasons for non-compliance with the protocol. *Dig Surg*. 2017;34(3):220-226.

39. Thacker JK, Mountford WK, Ernst FR, Krukas MR, Mythen MM. Perioperative fluid utilization variability and association with outcomes: considerations for enhanced recovery efforts in sample us surgical populations. *Ann Surg*. 2016;263(3):502-510.

Supplementary Online Content

Berian JR, Ban KA, Liu JB, et al. Association of an enhanced recovery pilot with length of stay in the National Surgical Quality Improvement Program. *JAMA Surg*. Published online December 20, 2017. doi:10.1001/jamasurg.2017.4906

eTable. Enhanced Recovery in NSQIP (ERIN) Variables

eFigure 1. Graphical Depiction of Balance Achieved in Propensity-Score Match

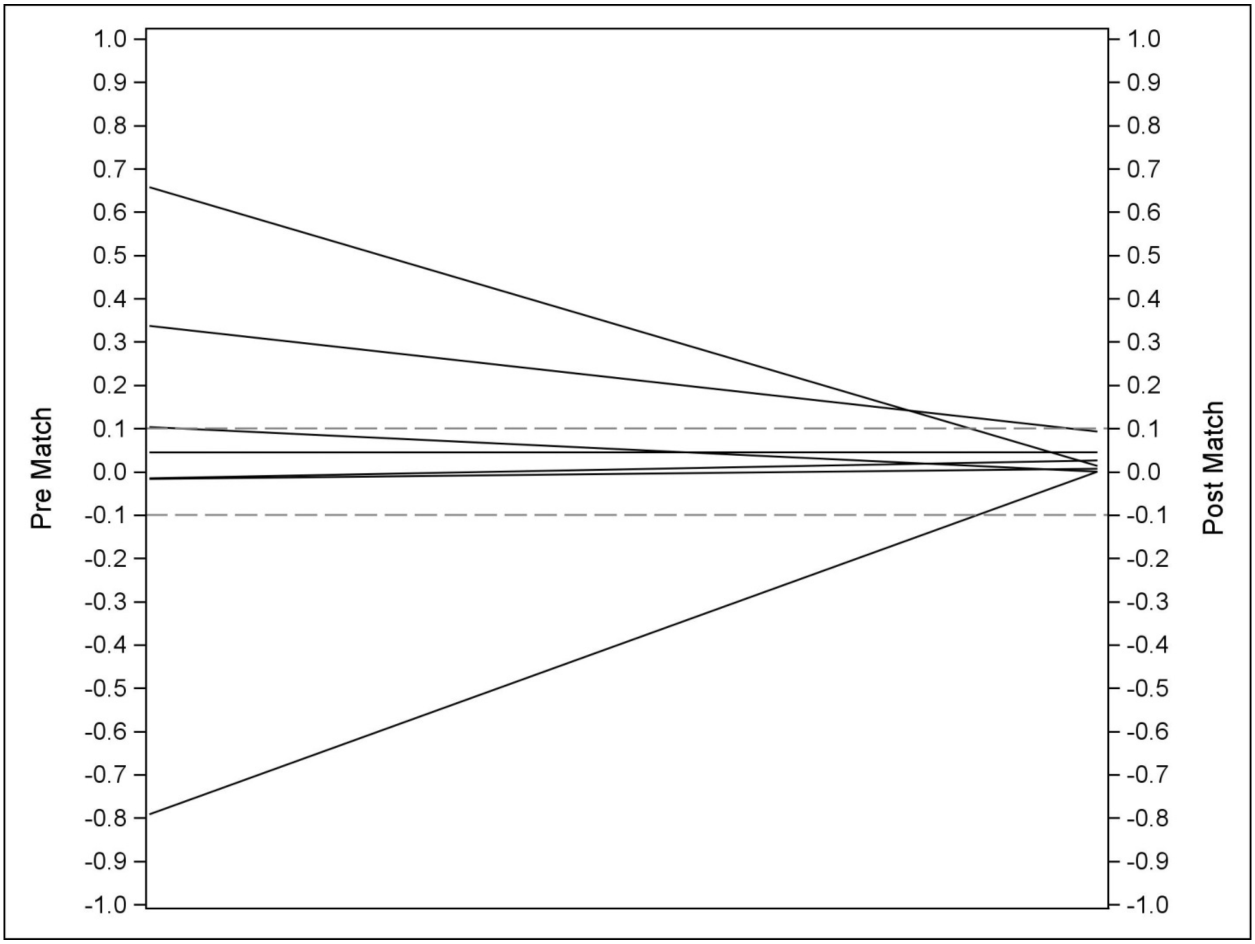
eFigure 2. Adherence With ERIN Process Elements Over Time

This supplementary material has been provided by the authors to give readers additional information about their work.

eTable. Enhanced Recovery in NSQIP (ERIN) Variables

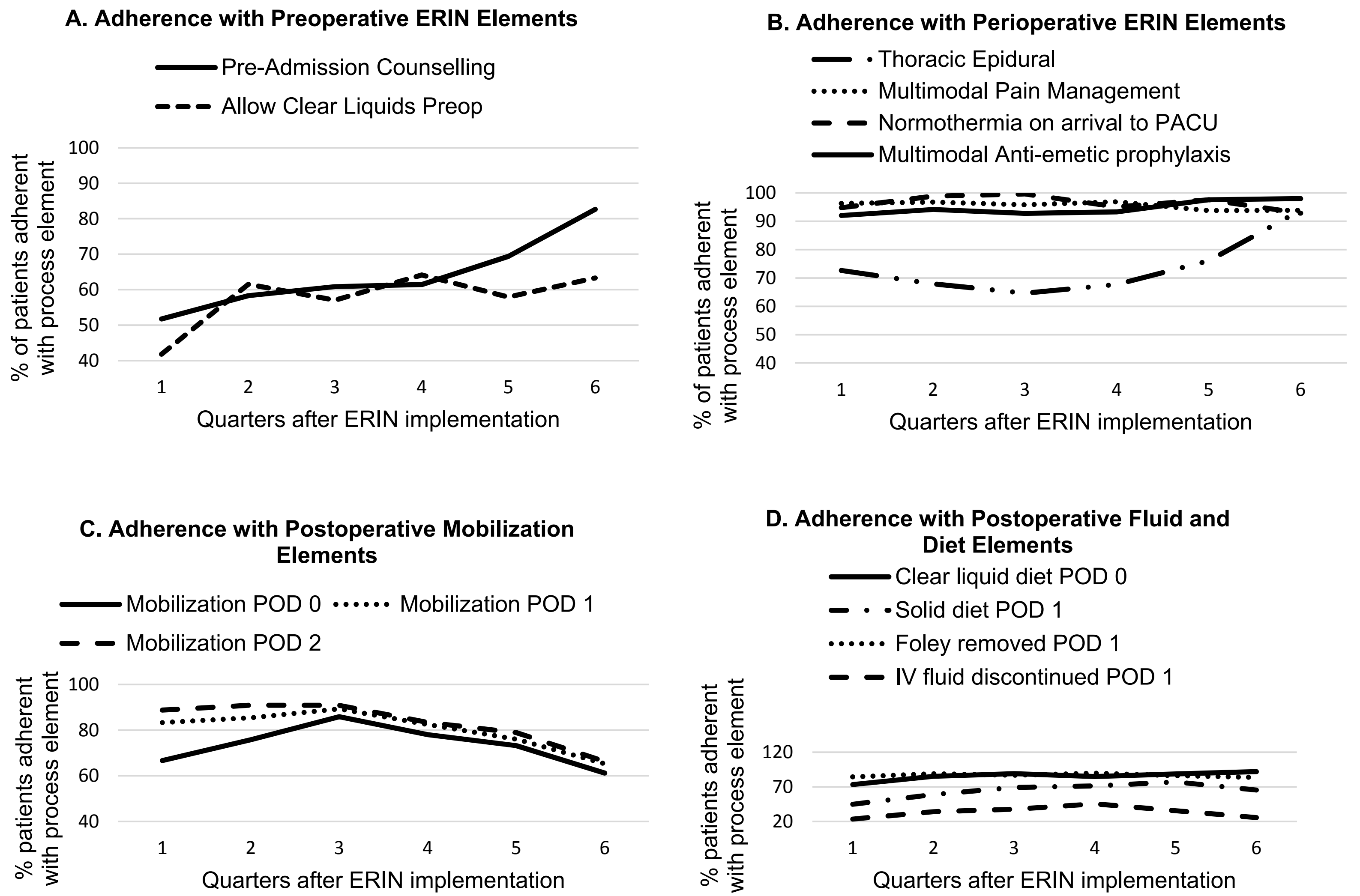
ERIN Variable	Response Options	Definition and Details
Preoperative Processes		
Pre-Admission Counseling	Yes, No	Provide written instructions detailing expectations and responsibilities (A) before surgery: fasting times, oral carbohydrate, showering/bathing; (B) after surgery: pain control, deep breathing and coughing exercises, mobility expectations, goals for nutritional intake, discharge criteria, and expected hospital stay
Allow clear liquids	Yes, No, No-High Risk	Allow patients to take clear liquids up to 3 hours before surgery. Clear liquids refer to transparent liquids that are easily digested, and include: water, juices without pulp, lemonade, sport drinks, clear broth, clear sodas, ice pops, tea, jello. High risk patients are those with: delayed gastric emptying, gastroparesis, gastrointestinal obstruction, upper gastrointestinal malignancy.
Perioperative Processes		
Thoracic epidural	Yes, No, No-Non-open surgery	Indicate whether a thoracic epidural was placed before surgery for patients undergoing open (non-laparoscopic) surgery. A thoracic epidural is placed in the T1-T12 levels, and is used for infusion of anesthetics (e.g., bupivacaine, lidocaine, mepivacaine, fentanyl, morphine) into the epidural space for pain control during and after surgery.
Multi-modal pain management	Yes, No	Use of non-opioid analgesics to reduce opioid-related side effects. Strategies or medications that would qualify include 2 or more of the following: Non-steroids anti-inflammatory drugs (NSAIDs), Acetaminophen, Gabapentinoids (gabapentin or pregabalin), Ketamine, Intravenous lidocaine (infusion), Thoracic epidural, Spinal analgesia, Regional blocks, Continuous wound infusion with local anesthetics (e.g., Marcaine pump, bupivacaine pump, etc.)
Normal temperature on arrival to PACU	Yes, No	The first measured temperature on arrival to post-anesthesia care unit (PACU) or intensive care unit (ICU) is >= 36.0o C / 96.8o F
Multi-modal anti-emetic prophylaxis	Yes, No	Document pre-operative screening of risk factors for post-operative nausea or vomiting. Risk factors include: Female, Non-smoking, History of motion sickness, History of post-operative nausea or vomiting, Preoperative / intraoperative / postoperative opioid use. Patients with two or more documented risk-factors should receive intraoperative anti-emetic interventions. Criteria are met if the patient has documented screening with < 2 risk factors OR if intraoperative anti-emetic interventions were used.
Postoperative Processes		
Mobilization within 24 hours	Yes, No	Indicate whether within the first 24 hours following surgery post-operative day #0-1, there is documentation that the patient ambulated for any length of time
Clear liquid diet within 24 hours	Yes, No	Indicate whether patients were given clear liquids within the first 24 hours following surgery.
Mobilization within 24-48	Yes, No	Indicate whether between 24-48 hours following surgery (POD#1-2), the patient ambulated for any length of time at least twice that

hours		day.
Solid diet within 24-48 hours	Yes, No	Indicate whether patients were given solid food between 24-48 hours following surgery (POD#1-2). Solid food indicates non-liquid, non-puree food (e.g., regular diet, low residue diet, cardiac/diabetic diet).
Foley removal within 48 hours	Yes, No, No-High risk	Indicate whether the urinary catheter was removed within the first 48 hours following surgery. High-risk patients for urinary retention are: History of benign prostatic hyperplasia (BPH), prostatitis, or prostate surgery; Extensive pelvic surgery or concern for bladder injury; History of previous post-operative urinary retention
Intravenous fluid discontinued within 24 hours	Yes, No	Determine whether the maintenance intravenous fluids were discontinued within the first 24 hours (POD#0-1) after surgery. Maintenance intravenous fluids are run at a continuous, steady rate (e.g., 42 – 150 cc/hour).
Mobilization within 48-72 hours	Yes, No	Indicate whether between 48-72 hours following surgery (POD#2-3), the patient ambulated for any length of time at least two times.



eFigure 1. Graphical Depiction of Balance Achieved in Propensity-Score Match

Standardized differences between the controls and pilot cases were plotted before vs. after propensity-score match.



eFigure 2. Adherence With ERIN Process Elements Over Time

(A) Preoperative ERIN Elements. (B) Perioperative ERIN Elements. (C) Postoperative Mobilization Elements. (D) Postoperative Fluid and Diet Elements. Each process was tracked as a binary variable. Graph represents % cases meeting compliance per quarter, over time.