Published in final edited form as:

J Am Coll Surg. 2019 April ; 228(4): 547–556.e8. doi:10.1016/j.jamcollsurg.2018.12.012.

First, Do No Harm: Rethinking Routine Diversion in Sphincter-Preserving Rectal Cancer Resection

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Abstract

Background: While diverting stomas have reduced anastomotic leak rates after sphincter-preserving proctectomy in some series, the effectiveness of routine diversion among a broad population of rectal cancer patients remains controversial. We hypothesized that routine temporary diversion is not associated with decreased rates of leak or reintervention in cancer patients at-large undergoing sphincter-sparing procedures.

Study Design: The Florida State Inpatient Database (Agency for Healthcare Research and Quality, Healthcare Cost and Utilization Project) was queried for patients undergoing sphincter-preserving proctectomy for cancer (2005–2014). Matched cohorts defined by diversion status were created using propensity scores based on patient and hospital characteristics. Incidence of anastomotic leak, non-elective reintervention, and readmission were compared, and cumulative 90-day inpatient costs were calculated.

Results: Of 8,620 eligible sphincter-sparing proctectomy recipients, 1,992 matched pairs were analyzed. Leak rates did not significantly vary between groups (4.5% vs. 4.3%, $p=0.76$), but diversion was associated with significantly higher odds of non-elective reintervention (2.37; 95%CI 1.90–2.96) and readmission (1.55; 95%CI 1.33 – 1.81) compared to undiverted patients. Median costs were higher among those diverted (\$21,325 vs \$15,050, $p<0.01$).

Conclusions: No association between diversion and anastomotic leak was found. However, temporary diversion was associated with increased incidence of non-elective reinterventions, readmissions, and higher costs. We therefore challenge the paradigm of routine diversion in rectal

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cancer surgery. Further study is needed to identify which patients would most benefit from diversion.

Precis

Within a statewide population of cancer patients undergoing sphincter-sparing proctectomy, we found no association between temporary diversion and anastomotic leak. Instead, stomas were associated with higher costs and more nonelective reinterventions and readmissions. We therefore challenge the paradigm of routine diversion after rectal cancer surgery.

Keywords

proctectomy; diversion; diverting ostomy; rectal cancer

Introduction

Anastomotic leak after sphincter-sparing proctectomy remains a widely feared and potentially devastating complication. Symptomatic leaks are typically associated with abdominal pain, fevers, peritonitis and/or sepsis often requiring hospitalization and invasive interventions.(1) Such anastomotic failures have also been associated with myriad negative consequences including increased perioperative mortality and morbidity, poorer functional outcomes, delays in adjuvant treatment, and decreased oncologic outcomes.(2–6) To decrease the frequency and severity of these leaks, many surgeons routinely divert patients undergoing sphincter-sparing proctectomy for cancer.(4, 7–10)

However, the net benefit of diversion remains unclear. While diverting stomas – often loop ileostomies – have been correlated with reductions in leak severity,(4, 7–10) their role in preventing symptomatic failures remains unclear in others.(11–13) Diversion has also been associated with significant morbidity, decreased quality of life, and increased healthcare utilization.(14–18) In addition, temporarily diverted patients seeking reversal require additional admissions and procedures, both carrying extra costs and complication risks.

Few studies have evaluated both the population-wide benefits (reduced leak rate and severity of sequelae) and costs (stoma-related complications, readmissions, and total healthcare costs) associated with routine diversion following sphincter-sparing proctectomy for cancer. Therefore, we performed the following analysis to better understand the complexities of fecal diversion in rectal cancer resection.

Methods

A retrospective cohort study was conducted using administrative billing data from the Florida State Inpatient Database (SID) for years 2005 through 2014. This SID, collected at the state level and made available by the Agency for Healthcare Research and Quality's (AHRQ) Healthcare Cost and Utilization Project (HCUP), included 22 million discrete discharges that occurred from all non-federal inpatient facilities in Florida during the study period.(19) The database contained core clinical and administrative variables including *International Classification of Diseases*, Ninth Revision, Clinical Modification (ICD-9-CM)

diagnosis and procedure codes, patient demographics, payer, total charges, and encrypted dates of admission, discharge, and procedure performance. Hospital characteristics were obtained from the American Hospital Association Annual Survey Database (Chicago, IL). The SID also included an encrypted patient identifier that facilitated longitudinal patient follow-up. The research protocol was deemed non-human research by the Washington University Institutional Review Board (IRB# 201802006).

Patient Selection and Exclusion

Patients undergoing elective sphincter-sparing proctectomy (ICD-9-CM procedure codes 48.61, 48.63, 48.64, 48.65, and 48.69) with or without diverting ostomy (codes 46.01, 46.11, 46.20, and 46.21) were selected. Laparoscopic and robotic modifier codes were used to identify surgical approach. Only patients with an associated diagnosis of distal colorectal malignancy were included. See eTable 1 for a complete list of associated procedure and diagnosis codes used for patient selection and variable definition.

Patients under 18 or over 90 years of age and those diagnosed with metastatic cancer, inflammatory bowel disease, or intraabdominal abscess or fistula in the year prior to the index admission were excluded. Index admissions with associated emergency department charges were deemed non-elective and excluded. To ensure that all patients were “at-risk” for experiencing the outcomes of interest, people who expired during the index admission or resided outside Florida were excluded from the final cohort.

Independent Variables

Demographic, medical comorbidity, and hospital variables were collected for propensity score matching and subsequent analyses. Age, sex, race, and home zip code median income quartile were provided by the SID. Medical comorbidities were determined by analyzing the index admission and all inpatient admissions in the 365 days preceding surgical resection with the enhanced Elixhauser algorithm as described by Quan.(20–22) Six comorbidities were selected for inclusion in propensity score matching based on their clinical relevance to ostomy creation and overall prevalence within the study cohort. The Elixhauser Mortality Index, a continuous weighted sum of all comorbidities defined within the original Elixhauser algorithm, was included in multivariable modeling to adjust for the total burden of underlying comorbidities.(23) Patients with procedure codes for vaginal, uterine, prostate, bladder, or liver procedures at time of proctectomy were considered to have multiorgan resections. Hospital academic affiliation was determined from the AHA data, while each facility’s surgical volume was calculated as the sum of proctectomies performed over the study period and then categorized into quartiles.

Propensity Score Matching

Following selection, patients were divided into treatment cohorts based on ostomy status after the index surgical procedure. To create groups at similar “risk” of undergoing diversion and control for significant covariate variation between cohorts in the included population, matching based on propensity scores was performed. A propensity score of diverting stoma creation was calculated for each patient using multivariable logistic regression that included patient-level demographic, socioeconomic, and treatment variables as well as hospital

volume and academic status (see eTable 2). Using a Greedy algorithm with a caliper distance of 0.2 times the standard deviation of the propensity score logit(24), undiverted patients were matched 1:1 without replacement to those with diverting stomas. Standardized differences of covariates between cohorts were calculated before and after matching, with values <0.1 signifying balance between groups (eFigure 1).(25) The distribution of propensity scores before and after matching were compared graphically (eFigure 2).(25)

Outcomes

The primary outcome was the incidence of anastomotic leak within 90 days of index proctectomy. As no ICD-9-CM code for anastomotic leak exists, we used a composite endpoint similar to that described by Kang et al. which included diagnoses likely to be associated with an anastomotic leak: postoperative peritonitis, intestinal perforation, intraabdominal or pelvic abscess, and abdominal or pelvic fistula.(26) The occurrence of a leak was considered a binary event.

Secondary outcomes included the incidence of non-elective reintervention, non-elective readmission, and elective ostomy reversal as well as total costs of all inpatient healthcare. Non-elective reinterventions were defined as any invasive abdominal or pelvic procedures other than elective ostomy reversal occurring during an inpatient admission. Procedures performed during the index admission but more than two days after the index surgery were considered reinterventions, as were all non-elective procedures from readmissions within the follow-up period. Reintervention was considered a binary variable and reported as the number of patients who underwent any reintervention during the follow-up period.

Non-elective readmissions were defined as inpatient readmissions with a primary discharge diagnosis other than adjuvant therapy or elective stoma reversal and were categorized based on the primary discharge diagnosis (eTable 1). Due to variability in length of readmissions, counts of readmissions were not analyzed; rather, this outcome was also considered a binary variable and reported as the number of patients experiencing at least one readmission within 90 days of surgery.

Total inpatient costs accrued over the 90-day study period were calculated using the following methodology. The SID included a total charge for all care provided per discharge record. Since charges vary widely between institutions and do not adequately reflect the cost of providing a particular service, the total charges per patient were converted to estimated costs using hospital and year-specific charge-to-cost ratios provided by HCUP.(27) These ratios, developed from hospital accounting reports from the Centers for Medicare and Medicaid Services, are specific to individual hospitals and represent estimations of expenses incurred by hospitals in treating individual patients.(28, 29) Therefore, reported costs estimate the total resources expended by inpatient facilities over the study period per patient. Physician and outpatient costs are not included.

The incidence of ostomy reversal was also compared between groups. Elective ostomy reversal was considered to occur at a readmission associated with 1) the appropriate ICD-9-CM procedure code (eTable 1), 2) a primary discharge diagnosis related to the stoma, and 3) no emergency department charges. A 2-year follow-up period from index procedure was

used for this outcome. To ensure equal follow-up time, proctectomies that occurred after 2012 were excluded from this analysis.

Statistical Analysis

All analyses were performed with SAS version 9.3 (SAS Institute, Cary, NC, USA). Univariate χ^2 , Kruskal-Wallis, and Student's t-tests were used to calculate descriptive statistics. The incidence of leak, readmission, and reintervention were compared between groups with χ^2 tests, while Kruskal-Wallis test was used to compare differences in median cost.

The McNemar test of difference of proportions was used to compare leak, reintervention, and readmission with calculation of odds ratios for matched pairs. For each outcome, the odds of the event occurring in diverted patients were compared to the odds in the undiverted cohort. Additional analysis of leak and reintervention were performed with hierarchical logistic regression models in the unmatched population with random intercept, fixed effects. Patients were clustered by the facility performing index proctectomy. Variables were selected manually for model inclusion based on clinical relevance to each modeled outcome.

Cost differences within each matched pair were calculated by subtracting the total costs of the undiverted patient from the total costs of his diverted match. The median cost difference was reported as the median difference in cost attributable to diversion within the matched pairs. Statistical significance was determined *a priori* to be $p < 0.05$ for all statistical testing, and all tests were two-sided. 95% confidence intervals for regression odds ratios were calculated by the Wald method, while confidence intervals for matched-pair odds ratios were approximated as described by Selvin.(30)

Results

8,620 patients who underwent sphincter-sparing proctectomy met study inclusion criteria (Figure 1). 2,142 were diverted at index operation, while the remaining 6,478 were not. Diverted patients tended to be younger (mean age 61.4 years vs 65.0 years; $p < 0.01$), male (63.7% vs 54.4%; $p < 0.01$), and more often treated with preoperative radiation (18.5% vs 3.4%; $p < 0.01$) compared to those without stomas (Table 1). They were also more likely treated at the highest volume centers (40.0% vs 18.1%; $p < 0.01$) and those affiliated with medical schools (61.8% vs 41.6%; $p < 0.01$).

After matching, the final sample included 3,984 patients evenly divided between diverted and undiverted patients. Adequate balance was achieved across all demographic, clinical, and hospital variables included in the match, with standardized mean differences less than 0.1 (eFigure 1 and eTable 3).

Outcomes

The incidence of anastomotic leak did not differ significantly by diversion status; 89 diverted patients experienced a leak compared to 85 undiverted patients (4.5% vs 4.3%, respectively; $p = 0.76$) (Table 2). Approximately half of all leaks were diagnosed during the index admission. Significantly more diverted patients underwent non-elective reintervention

(14.1% vs 6.4%; $p<0.01$) and readmission (25.7% vs 18.3%; $p<0.01$) within 90 days of proctectomy compared to those without stomas. In addition, the median total costs among the diverted cohort was significantly higher than the median costs of undiverted patients (\$21,325 vs \$15,050; $p<0.01$). Finally, electively-diverted patients were reversed at a higher rate than undiverted patients who required subsequent stomas (88% vs 74%, $p=0.01$) (eFigure 3).

Specific reintervention procedure and readmission indication also varied based on stoma status. Excluding elective stoma reversal, percutaneous drain placement (19.7%), small bowel resection (19.7%), and lysis of adhesions (8.9%) were the most common reinterventions performed among patients with diverting stomas; percutaneous drain placement (11.5%) and ileostomy creation (5.9%) were the most frequent procedures performed in the undiverted group (Figure 2). Conditions associated with unregulated ileostomy output, such as kidney injury (16.4%) and dehydration (9.8%), were the most frequent reasons for readmission in ostomates, while infections (7.1%) and leaks (6.1%) were the most common among undiverted people (Figure 3). Within matched pairs, temporary diversion was not significantly associated with risk of leak (OR 0.95; 95%CI 0.70 – 1.29) (eTable 4). However, risks of reintervention and readmission were 2.37 (95%CI 1.90 – 2.96) and 1.55-fold higher (95%CI 1.33 – 1.81), respectively, among diverted persons compared to matched controls. Additionally, the median cost difference between diverted and undiverted patients was \$5,574 (IQR: -\$2,071 - \$14,197) (Figure 4). Among all patients with anastomotic leak, median costs were higher but did not significantly differ by diversion status (eTable 5).

In hierarchical multivariable regression analysis, the presence of diverting ostomy remained unassociated with leaks (OR 0.99, 95%CI 0.71 – 1.37, $p=0.93$) despite the association of radiation, age, and overall mortality index with anastomotic failures (eTable 6). Similar analysis of reintervention, however, revealed a 2.76-fold increased risk among ostomates (OR 2.76; 95%CI 2.14 – 3.58, $p<0.01$) (eTable 7).

Discussion

In this population study of patients undergoing proctectomy for cancer, temporary diversion was not associated with lower incidence of anastomotic leak. Instead, diverting stomas were associated with significantly higher risk of non-elective readmissions and reinterventions as well as higher total costs after controlling for patient demographics and burden of disease, variations in surgical approach and extent, and hospital-level factors.

These findings add to the controversy regarding routine temporary diversion in patients undergoing rectal cancer resection. Several randomized studies have argued that fecal diversion reduces the prevalence of leak or the severity of its sequelae. The largest, performed by Chude et al.(31), found anastomotic leaks in 2% of diverted patients compared to 10% in those without stomas among rectal cancer patients with tumors less than 6cm from the anal verge. Matthiessen and colleagues(7) also reported higher leak rates among undiverted patients – 28% vs 10% - in their randomized analysis of over 200 Swedish participants with tumor heights of 7cm or less. Of the 33 patients that leaked in their

undiverted cohort, 28 required reoperation and diversion. Another randomized study by Ulrich et al.(8) was halted prematurely when a 37% leak rate among 16 undiverted patients was found on interim analysis. And, several non-randomized and *post-hoc* analyses have identified increased incidence of either symptomatic leak or reoperation among patients who were not diverted or drained after initial operation.(10, 32–35) Based on these data, many in the surgical community routinely divert rectal cancer patients undergoing sphincter-sparing resections.

Other studies, however, raise questions about this practice. Shiomi et al.(36) reported no difference in leak rates between diverted and undiverted cohorts in their prospective multicenter study of 1,000 patients with tumors 10cm or less from the anus. Kang and colleagues(26) found a *higher* incidence of leak among diverted patients in their nationwide retrospective series, mirroring results from several earlier studies.(4, 11, 37) Other groups have focused on the sequelae of diversion, noting a higher rate of postoperative complications(18) or overall healthcare utilization(14) among ostomates compared to undiverted people. Most interestingly, long-term follow-up from Matthiessen's prospective trial – a study widely cited in support of routine diversion – found more readmissions and increased overall costs (€1,663 vs €5,922, $p<0.01$) in the patients randomized to diversion despite the significantly lower leak rate in that group.(38) The authors concluded that while diversion did reduce the clinical leak rate, it was not a cost-effective intervention.

Within this context, we draw several conclusions from our study. First, diversion is not a benign procedure. While easily performed and perioperatively tolerated, ileostomies are difficult to manage and are associated with repeated procedures and readmissions, higher costs, and lower quality of life.

Second, diversion does not appear effective across a population of sphincter-sparing proctectomy patients. Though randomized trials have shown stomas *efficacious* in select patients at high risk of leak, these same outcomes are not achieved among all-comers. This lack of *effectiveness* on the population level is likely explained by the greater variability in risk factors among our study cohort. For example, low tumors – the only type included in the Matthiessen and Chude studies – are likely less prevalent among our cohort. The cohort therefore has an overall lower cumulative risk of leak compared to the randomized samples, which in turn weakens the effect of diversion applied at-large. Thus, while diversion may benefit specific patients, it does not appear effective in our population.

Third, anastomotic leaks are associated with poor outcomes and high costs regardless of diversion status. And, undiverted patients who leak and undergo subsequent diversion are still able to undergo stoma reversal in the majority cases.

In summary, this study further suggests that diversion should be used selectively among patients undergoing sphincter-preserving proctectomy for cancer. While appropriate in certain cases, the significant morbidity and costs of routine diversion outweigh the clinical benefit among the atlarge rectal cancer population.

Limitations

Several limitations to this study must be considered. First, the retrospective design potentially introduces confounding by indication and selection bias. To reduce the impact of this bias, we performed propensity score matched-pair analysis and hierarchical regression modeling of the complete cohort to assess the association of diversion with the outcomes of interest. But, since neither method can completely negate such bias, we can only conclude that associations exist between diversion and the observed outcomes. The causal nature of these relationships cannot be assessed here.

Second, the analysis is inherently limited to data included in the discharge billing summary. These records are prepared by coding personnel for reimbursement purposes. Therefore, some clinical details relevant to rectal cancer treatment, such as tumor height or history of pelvic radiotherapy, are either unavailable or under-coded. For example, neoadjuvant radiation – recommended for most patients with nonmetastatic rectal cancer – was documented for less than 15% of this cohort. Due to the limitations associated with these two variables in particular, we were unable to fully evaluate the specific impact of diversion in irradiated patients with low tumors. Future evaluation of these factors in a population-level analysis is needed.

Third, no specific ICD-9-CM diagnosis code exists for anastomotic leak, and clinical definitions vary substantially.⁽¹⁾ A composite variable that included various diagnoses likely to represent leaks in patients who have had rectal surgery – postoperative fistulas, intraabdominal abscesses, and peritonitis – was therefore used. Previous investigators have taken similar approaches⁽²⁶⁾, but variation in code selection may contribute to significant differences in outcomes between studies of administrative data. However, this method should facilitate relative comparison within a single study population so long as a consistent definition is used throughout.

Conclusion

Using a longitudinal administrative database, we found that temporary diversion in patients undergoing sphincter-sparing proctectomy for cancer was not associated with decreased anastomotic leaks. However, diverting ostomy was associated with higher incidence of nonelective readmission and reintervention within 90 days, as well as greater total costs over the study period. We conclude that diversion should be used thoughtfully in this patient population in light of the costs and complications associated with temporary stomas. Further study is needed to identify patients undergoing proctectomy who are most likely to benefit from diversion.

Acknowledgments

Disclosure Information: Nothing to disclose.

Support: Research reported in this publication was supported by the Washington University School of Medicine Surgical Oncology Basic Science and Translational Research Training Program grant T32CA009621 from the National Cancer Institute (NCI). The Washington University Center for Administrative Data Research is supported in part by the Washington University Institute of Clinical and Translational Sciences grant UL1 TR002345 from the

National Center for Advancing Translational Sciences of the NIH, and grant number R24 HS19455 through the Agency for Healthcare Research and Quality.

Presented at the Southern Surgical Association 130th Annual Meeting, Palm Beach, FL, December 2018.

Abbreviation Master List:

HCUP	Healthcare Cost and Utilization Project
AHRQ	Agency for Healthcare Research and Quality
SID	State Inpatient Database
ICD-9-CM	<i>International Classification of Diseases</i> , Ninth Revision, Clinical Modification

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Figure 1.
Flow diagram of study population selection.

Figure 2.

Reinterventions performed based on diversion status. Distribution of the 10 most common reinterventions performed within 90 days of index proctectomy among the diverted (orange) and undiverted (blue) populations. Percentages were calculated from a total of all reinterventions performed across both groups. *Each of these categories account for <1.9% of total reinterventions. Due to the small number, the data use agreement prohibited reporting of these exact percentages.

Figure 3.

Indications for readmission based on diversion status. Distribution of principal diagnoses associated with readmissions in the diverted (orange) and undiverted (blue) cohorts after proctectomy for cancer. Percents were calculated from a total of all readmissions that occurred across both cohorts. *Each of these categories account for < 0.9% of total readmissions. Due to the small number of readmissions, the data use agreement prohibited reporting of these exact percentages.

Figure 4.

Cost differences within matched pairs. Cost difference within matched pairs is calculated by subtracting the total cost of the undiverted patient from the total cost of their matched counterpart. Negative values denote pairs where the undiverted patient generated higher costs than the diverted patient. Pairs where no leak occurred are depicted in blue. Pairs in which the diverted member suffered a leak are denoted in yellow, and pairs in which the undiverted member leaked are pictured in red. USD, US dollars; IQR, interquartile range.

eFigure 1.

Matched pair standardized mean differences before and after matching. The standardized mean difference between diverted and undiverted cohorts of patient demographic, comorbidity, and treatment related variables. Differences both before (red dots) and after (blue dots) matching are displayed. Sufficient balance between cohorts is assumed wherever the standardized difference is < 0.1 (dashed line) after matching. Lap, laparoscopic.

eFigure 2.

Propensity score distributions. Distribution of propensity scores among cohorts (A) before and (B) after matching. Propensity scores of undiverted patients represented in blue, diverted scores in red.

eFigure 3.

Time to ostomy reversal. Cumulative frequency of ostomy reversal during 2-year follow-up in the (A) electively diverted and (B) initially undiverted populations; patients represented in (B) underwent subsequent diversion after leaking. Overall reversal rates within the follow-up period were 88% and 74%, respectively.

Table 1.

Study Cohort Characteristics, before Matching

Variables	Diverted, n = 2,142	Undiverted, n = 6,478	p Value	Standardized mean difference
Age, y, mean (SD)	61.4 (12.0)	65.0 (12.3)	<0.01	0.30
Sex, male, n (%)	1,365 (63.7)	3,521 (54.4)	<0.01	0.19
Race, n (%)			<0.01	
White	1,542 (72.5)	4,906 (76.4)		0.09
Black	135 (6.3)	416 (6.5)		<0.01
Hispanic	360 (16.9)	839 (13.1)		0.11
Other	91 (4.3)	260 (4.1)		0.01
Home zip code median income quartile, n (%) *			0.22	
1, \$1 – 40,999	539 (27.7)	1,555 (27.8)		0.03
2, \$41,000 – 50,999	601 (30.9)	1,856 (33.2)		0.01
3, \$51,000 – 66,999	537 (27.6)	1,484 (26.5)		0.05
4, >\$67,000	266 (13.7)	704 (12.6)		0.04
Comorbidities, n (%)				
Obesity	219 (10.2)	645 (10.0)	0.72	0.01
Diabetes mellitus	394 (18.4)	1,288 (19.9)	0.13	0.04
COPD	259 (12.1)	1,027 (15.9)	<0.01	0.11
Electrolyte abnormality	558 (26.1)	1,303 (20.1)	<0.01	0.14
Congestive heart failure	76 (3.4)	333 (5.1)	<0.01	0.08
Renal failure	78 (3.6)	270 (4.2)	0.28	0.03
Elixhauser Mortality Index score, median (IQR)	7 (6 – 15)	7 (6 – 12)	<0.01	0.06
Admitting hospital type, n (%)			<0.01	0.41
Teaching	1,322 (61.8)	2,691 (41.6)		
Nonteaching	819 (38.2)	3,780 (58.4)		
Admitting hospital volume quartile, n (%)			<0.01	
1, <60	361 (16.9)	2,299 (35.5)		0.43
2, 60 – 120	384 (17.9)	1,723 (26.6)		0.21
3, 121 – 240	541 (25.3)	1,283 (19.8)		0.13
4, >240	856 (40.0)	1,173 (18.1)		0.50
History of radiation, yes, n (%)	397 (18.5)	221 (3.4)	<0.01	0.50
Surgical approach, n (%)			<0.01	
Open	1,687 (78.8)	5,316 (82.1)		0.08
Laparoscopic	281 (13.1)	878 (13.6)		0.01
Robotic	174 (8.1)	284 (4.4)		0.15
Multi-organ resection, yes, n (%)	79 (3.7)	182 (2.8)	0.04	0.05

* The median income quartile limits change year-to-year; for general reference, the values for the middle year of this study, 2010, are listed.
IQR, interquartile range.

Table 2.

Primary and Secondary Outcomes, Unadjusted

Outcome	Diverted, n = 1,992	Undiverted, n = 1,992	p Value
Anastomotic leak, n (%)			0.76
Total	89 (4.5)	85 (4.3)	
Index admission	42 (2.1)	43 (2.2)	
Readmission	47 (2.4)	42 (2.1)	
Reintervention, n (%)			<0.01 *
Total	280 (14.1)	127 (6.4)	
Index admission	66 (3.3)	54 (2.7)	
Readmission	214 (11.1)	73 (3.8)	
Readmission, n (%)			<0.01 *
Non-elective	511 (25.7)	364 (18.3)	
Elective [†]	603 (30.3)	55 (2.8)	
Total cost (\$), median (IQR)	21,325 (15,650 – 28,986)	15,050 (11,134 – 21,103)	<0.01 *

* Significant.

[†] Elective readmissions are defined as any 90-day readmission for adjuvant treatment or ostomy reversal without associated emergency department charges.

IQR, interquartile range.

eTable 1.

Variable Definitions using ICD-9-CM Diagnosis and Procedure Codes

Category, clinical variable	Associated ICD-9-CM Codes
Inclusion criteria	
Sphincter-sparing proctectomy	48.61, 48.63, 48.64, 48.65, 48.69
Diverting ostomy	46.01, 46.11, 46.20, 46.21
Malignancy	153.1, 153.2, 153.3, 153.7, 153.8, 153.9, 154.0, 154.1, 154.2, 154.3, 154.8
Descriptive variables	
Laparoscopic approach	17.31, 17.32, 17.33, 17.34, 17.35, 17.36, 17.39, 54.51
Robotic approach	17.41, 17.42, 17.49
Comorbidities	See Elixhauser et al. and Quan et al. ²⁰⁻²²
History of radiation	V15.3, 558.1
Multi-organ resection (procedure) *	50.21, 50.22, 50.23, 50.24, 50.25, 50.26, 50.29, 50.3, 57.6, 57.71, 57.79, 60.0, 60.11, 60.12, 60.13, 60.14, 60.15, 60.18, 60.19, 60.21, 60.29, 60.3, 60.4, 60.5, 60.61, 60.62, 60.69, 60.71, 60.72, 60.73, 60.79, 60.81, 60.82, 60.91, 60.92, 60.93, 60.94, 60.95, 60.96, 60.97, 60.99, 68.0, 68.11, 68.12, 68.13, 68.14, 68.15, 68.16, 68.19, 68.21, 68.22, 68.23, 68.24, 68.25, 68.29, 68.31, 68.39, 68.41, 68.49, 68.51, 68.59, 68.61, 68.69, 68.71, 68.79, 68.8, 68.9, 69.19, 70.31, 70.32, 70.33, 70.4, 70.61, 70.62, 70.63, 70.64
Elective ostomy reversal	46.50, 46.51, 46.52
Outcomes	
Anastomotic leak	567.21, 567.22, 567.23, 567.29, 569.5, 569.81, 569.83, 619.1, 998.6
Readmission indication	
Soft tissue and systemic infection	003.1, 038.0, 038.10, 038.11, 038.12, 038.19, 038.2, 038.3, 038.40, 038.41, 038.42, 038.43, 038.44, 038.49, 038.8, 038.9, 112.5, 112.85, 536.41, 558.2, 566, 567.1, 567.31, 567.38, 567.89, 572.0, 616.4, 682.2, 682.5, 682.6, 686.1, 728.86, 780.60, 780.62, 790.7, 995.91, 995.92, 998.51, 998.59, 999.31, 999.32
Ostomy complications	V55.2 [†] , V55.3 [†] , V55.4 [†] , 569.60, 569.61, 569.62, 569.69
Acute kidney injury and other genitourinary complications	584.5, 584.6, 584.7, 584.8, 584.9, 591, 585.6, 585.9, 593.3, 593.4, 593.5, 593.8, 593.9, 595.0, 595.82, 595.89, 596.0, 596.2, 596.54, 596.6, 598.2, 599.0, 599.1, 599.60, 599.7, 599.84, 600.21, 600.91, 608.83, 608.86, 614.9, 619.0, 788.1, 788.20, 788.30, 788.99, 867.0, 867.1, 867.2, 867.3, 996.64, 996.65, 996.76
Cardiac complications	410.01, 410.11, 410.21, 410.31, 410.41, 410.51, 410.61, 410.71, 410.81, 410.91, 411.81, 414.8, 427.0, 427.1, 427.3, 427.4, 427.5, 427.61, 427.69, 427.81, 427.89, 427.9, 428.21, 429.83, 786.50, 786.51, 786.52, 786.59, 794.31
Pulmonary complications	480.0, 480.1, 480.2, 480.3, 480.8, 480.9, 481, 482.0, 482.1, 482.2, 482.30, 482.31, 482.32, 482.39, 482.40, 482.41, 482.42, 482.49, 482.81, 482.82, 482.83, 482.84, 482.89, 482.9, 485, 486, 512.1, 512.8, 514, 515, 516.8, 518.0, 518.81, 519.19, 786.05, 786.06, 786.09, 799.02
Vascular thrombotic complications	452, 415.11, 415.12, 415.13, 415.19, 451.11, 451.19, 451.2, 451.81, 453.2, 453.40, 453.41, 453.42
Hemorrhage and acute anemia	280.0, 285.1, 459.0, 562.02, 562.12, 568.81 569.3, 578.1, 578.9, 596.7, 998.11, 998.12
Gastrointestinal complications and malnutrition	008.41, 008.42, 008.43, 008.44, 008.45, 008.46, 008.47, 008.49, 008.5, 009.0, 009.1, 009.3, 261, 262, 263.0, 263.1, 263.2, 263.3, 263.9, 568.0, 569.1, 569.2, 569.7, 569.49, 570, 572.0, 572.1, 573.4 577.0, 577.1, 577.2, 577.8, 577.9, 579.3, 579.9, 783.0, 783.2, 783.3, 783.7, 783.9, 787.0, 787.3, 787.6, 787.91, 997.4, 936, V55.1
Anastomotic leak	Same as above
Dehydration and electrolyte abnormalities	250.0, 275.2, 275.3, 275.4, 276.0, 276.1, 276.2, 276.3, 276.4, 276.5, 276.7, 276.8, 276.9, 458.0, 458.29, 458.8, 458.9, 785.59

Category, clinical variable	Associated ICD-9-CM Codes
Pain	569.41, 569.42, 569.43, 789.00, 789.01, 789.03, 789.04, 789.05, 789.06, 789.07, 789.09, 789.3, 789.6, 338.18, 338.19, 338.28, 338.29, 338.3
Ileus or bowel obstruction	560.0, 560.1, 560.2, 560.30, 560.31, 560.32, 560.39, 560.81, 560.89, 560.9, 564.00, 564.09, 564.1, 564.2, 564.3, 564.4, 564.5, 564.6, 564.7, 564.89, 564.9, 568.0, 568.81, 568.82, 568.89
Wound complications including hernias	551.00, 551.01, 551.02, 551.03, 551.1, 551.20, 551.21, 551.29, 551.3, 551.8, 551.9, 552.00, 552.01, 552.02, 552.03, 552.1, 552.20, 552.21, 552.29, 552.3, 552.8, 552.9, 553.0, 553.1, 553.2, 553.3, 553.8, 553.9, 707.00, 707.01, 707.02, 707.03, 707.04, 707.05, 707.06, 707.07, 707.09, 707.10, 707.12, 707.13, 707.14, 707.15, 707.19, 707.20, 707.21, 707.22, 707.23, 707.24, 707.25, 707.8, 707.9, 998.13, 998.30, 998.31, 998.32, 998.33
Elective readmission for adjuvant therapy	V58.11, V58.12
Elective readmission for ostomy reversal	V55.2 [†] , V55.3 [†] , V55.4 [†] , V58.41, V58.42
Reintervention	See Figure 2.
Elective stoma reversal [‡]	46.50, 46.51, 46.52

* These codes are used to designate a multi-organ resection if used simultaneously with a partial proctectomy code and diagnosis of malignancy.

[†] These codes are considered ostomy complications if associated with an admission that includes emergency department charges. If associated with procedure codes for ostomy reversal but no ED charges, then these codes are considered to represent an admission for elective ostomy reversal.

[‡] If not associated with emergency department charges during the admission where these procedure codes were used, then these procedures are assumed to represent an elective stoma closure.

eTable 2.

Variables Included in Propensity Score Calculation

Variable	Type
Age	Continuous
Sex	Binary
Comorbidities	
Obesity	Binary
Diabetes mellitus	Binary
Chronic obstructive lung disease	Binary
Electrolyte abnormality	Binary
Congestive heart failure	Binary
Renal failure	Binary
Race	Categorical
Quartile of home zip code median income	Categorical
History of radiation therapy	Binary
Surgical approach	Categorical
Multi-organ resection	Binary
Admitting hospital proctectomy volume	Categorical
Hospital academic affiliation	Binary

eTable 3.**Matched Population Characteristics**

Variables	Diverted, n= 1,992	Undiverted, n= 1,992	p Value	Standardized mean difference
Age, y, mean (SD)	61.9 (11.8)	61.6 (12.4)	0.42	0.03
Sex, male, n (%)	1,254 (63.0)	1,270 (63.8)	0.60	0.02
Race, n (%)				
White	1,429 (71.7)	1,425 (71.5)		<0.01
Black	124 (6.2)	115 (5.8)	0.89	0.02
Hispanic	338 (17.0)	353 (17.7)		0.02
Other	88 (4.4)	84 (4.2)		0.01
Home zip code median income quartile, n (%) *				
1, \$1 – 40,999	487 (24.5)	476 (23.9)		0.01
2, \$41,000 – 50,999	561 (28.2)	604 (30.3)	0.76	0.05
3, \$51,000 – 66,999	501 (25.2)	476 (23.9)		0.03
4, \$67,000	249 (12.5)	248 (12.5)		<0.01
Comorbidities, n (%)				
Obesity	205 (10.3)	202 (10.1)	0.88	<0.01
Diabetes mellitus	366 (18.4)	370 (18.6)	0.87	0.01
Chronic obstructive lung disease	252 (12.7)	228 (11.5)	0.24	0.04
Electrolyte abnormality	509 (25.6)	493 (24.8)	0.56	0.02
Congestive heart failure	72 (3.6)	69 (3.5)	0.80	0.01
Renal failure	76 (3.8)	77 (3.9)	0.93	<0.01
Elixhauser Mortality Index Score, median (IQR)	7 (6 – 15)	7 (6 – 13)	0.06	
Admitting hospital type, n (%)				
Teaching	1,184 (59.4)	1,160 (58.2)	0.44	0.02
Nonteaching	808 (40.6)	832 (41.8)		
Admitting hospital volume quartile, n (%) [‡]				
1, <60	358 (18.0)	348 (17.8)		0.01
2, 60 – 120	379 (19.0)	390 (19.6)	0.62	0.01
3, 121 – 240	512 (25.7)	489 (24.6)		0.03
4, >240	743 (37.3)	765 (38.4)		0.02
History of radiation, yes, n (%)	257 (12.9)	202 (10.1)	0.01	0.09
Surgical approach, n (%)				
Open	1,581 (79.4)	1,584 (79.5)		<0.01
Laparoscopic	259 (13.0)	257 (12.9)	0.91	<0.01
Robotic	152 (7.6)	151 (7.6)		<0.01
Multi-organ resection, yes, n (%) [‡]	72 (3.6)	77 (3.9)	0.68	0.01

* Median income per zip code changes over the study period. For general reference, the median incomes for the middle year of this study, 2010, are listed in the table.

[†]Defined as the sum of sphincter-sparing proctectomies performed during the study period.

[‡]Includes resection codes for bladder, prostate, vaginal, uterine, or liver resection performed at time of index proctectomy

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eTable 4.**Outcomes Attributable to Diverting Ostomy, Matched Pair Analysis**

Outcome	Odds ratio (95% CI) *	p Value
Anastomotic leak	0.95 (0.70 – 1.29)	0.76
Reintervention within 90 d	2.37 (1.90 – 2.96)	<0.01
Readmission within 90 d	1.55 (1.33 – 1.81)	<0.01

* Displayed odds ratios compare the odds of diverted patients experiencing the specified outcome compared to the odds of undiverted patients experiencing the same event within matched pairs. Confidence intervals for matched pair odds ratios were approximated as described by Selvin,³⁰ and significance testing was performed with McNemar's Test of difference in proportions.

eTable 5.

Median Costs among Patients with Leak, by Diversion Status

Diversion status	Median total cost, \$	Interquartile range	p Value
Diverted, n = 89	37,608	25,043 – 53,171	0.31
Undiverted, n = 85	41,363	26,682 – 71,957	

eTable 6.**Multivariable Logistic Regression of Anastomotic Leak**

Variable	Model of anastomotic leak			
	Odds ratio	95% CI		p Value
Diverting ostomy				
Yes	0.91	0.69	1.20	0.51
No	Reference			
Age	0.98 *	0.97	0.99	<0.01
Sex				
Male	Reference			
Female	0.84	0.67	1.07	0.15
Elixhauser Mortality Index [†]	1.06*	1.05	1.08	<0.01
Race				
White	Reference			
Black	0.88	0.56	1.38	
Hispanic	0.83	0.58	1.19	
Other	0.76	0.41	1.34	0.60
Home zip code median income quartile [‡]				
1, \$1 – 40,999	Reference			
2, \$41,000 – 50,999	1.07	0.81	1.43	
3, \$51,000 – 66,999	0.91	0.66	1.24	
4, >\$67,000	1.02	0.70	1.49	0.73
Admitting hospital affiliation				
Teaching	1.03	0.80	1.34	0.80
Nonteaching	Reference			
Admitting hospital volume quartile [§]				
1, <60	Reference			
2, 60 – 120	1.18	0.88	1.58	
3, 121 – 240	0.95	0.68	1.32	
4, >240	0.74	0.51	1.07	
History of radiation, yes	1.60 *	1.09	2.34	0.02
Surgical approach				
Open	Reference			
Laparoscopic	1.30	0.96	1.77	0.21
Robotic	1.20	0.76	1.89	
Multi-organ resection, yes	1.55	0.86	2.79	0.14

* Odds ratios denote statistically significant associations.

[†]The Elixhauser mortality index is a weighted sum of 29 independent comorbidities used to incorporate the influence of comorbid conditions on inpatient mortality. For this model, the index is used as a surrogate for overall comorbidity burden as relates to a patient's risk of anastomotic leak.

[‡]Median income per zip code changes over the study period. For general reference, the median incomes for the middle year of this study, 2010, are listed in the table.

[§]Defined as the sum of sphincter-sparing proctectomies performed during the study period.

// Includes resection codes for bladder, prostate, vaginal, uterine, or liver resection performed at time of index proctectomy.

eTable 7.**Multivariable Logistic Regression of Nonelective Reintervention**

Variable	Model of reintervention			
	Odds ratio	95% CI		p Value
Anastomotic leak				
Yes	30.22 *	23.38	39.06	<0.01
No	Reference			
Diverting ostomy				
Yes	2.90 *	2.37	3.55	<0.01
No	Reference			
Age	0.99	0.98	1.00	0.08
Sex				
Male	Reference			
Female	0.98	0.81	1.19	0.0
Elixhauser Mortality Index [†]	1.03 *	1.02	1.04	<0.01
Race				
White	Reference			
Black	0.99	0.68	1.47	0.55
Hispanic	1.19	0.92	1.54	
Other	0.90	0.56	1.44	
Home zip code median income quartile [‡]				
1, \$1 – 40,999	Reference			
2, \$41,000 – 50,999	0.97	0.76	1.25	<0.01
3, \$51,000 – 66,999	1.42*	1.11	1.82	
4, >\$67,000	1.32	0.97	1.79	
Admitting hospital affiliation				
Teaching	1.00	0.81	1.24	0.99
Nonteaching	Reference			
Admitting hospital volume quartile [§]				
1, <60	Reference			
2, 60 – 120	1.01	0.79	1.30	
3, 121 – 240	0.96	0.73	1.25	
4, >240	0.83	0.63	1.09	0.49
History of radiation, yes	0.67*	0.47	0.95	0.02
Surgical approach				
Open	Reference			
Laparoscopic	1.65 *	1.30	2.10	<0.01
Robotic	1.25	0.87	1.80	

Variable	Model of reintervention			
	Odds ratio	95% CI		p Value
Multi-organ resection, yes	0.76	0.42	1.37	0.36

* Odds ratios denote statistically significant associations.

[†]The Elixhauser mortality index is a weighted sum of 29 independent comorbidities used to incorporate the influence of comorbid conditions on inpatient mortality. For this model, the index is used as a surrogate for overall comorbidity burden as relates to a patient's risk of anastomotic leak.

[‡]Median income per zip code changes over the study period. For general reference, the median incomes for the middle year of this study, 2010, are listed in the table.

[§]Defined as the sum of sphincter-sparing proctectomies performed during the study period.

^{||}Includes resection codes for bladder, prostate, vaginal, uterine, or liver resection performed at time of index proctectomy.