30-day readmission after radical cystectomy: Identifying targets for improvement using the phases of surgical care

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Abstract

Introduction: Postoperative readmissions following radical cystectomy (RC) have gained attention in the past decade. Postoperative and post-discharge complications play a role in readmission rates; however, our ability to predict readmissions remains poor.

Methods: Using the National Surgical Quality Improvement Program database, we identified patients with bladder cancer undergoing RC from 2013–2015. Complications were defined as postoperative and post-discharge. Outcomes were 30-day readmission, post-discharge complications, and post-discharge major complications. Patient, operative, and complication factors were assessed using multivariable logistic regression.

Results: We identified 4457 patients who underwent RC; 9.2% of patients experienced a postoperative complication, 18.8% experienced a post-discharge complication, and 20.3% were readmitted. Overweight and obese body mass index (BMI), dependent functional status, chronic obstructive pulmonary disease (COPD), a continent diversion, and duration of operation were associated with post-discharge complications. Postoperative complications were not associated with post-discharge complications. Readmission was associated with Black race (odds ratio [OR] 1.5; 95% confidence interval [CI] 1.0–2.1), overweight (OR 1.5; 95% CI 1.2–1.8) and obese BMI (OR 1.5; 95% CI 1.2–1.9), diabetes (OR 1.2; 95% CI 1.0–1.5), COPD (OR 1.4; 95% CI 1.0–1.8), steroid use (OR 1.5; 95% CI 1.0–2.2), a continent diversion (OR 1.4; 95% CI 1.1–1.7), duration of operation (OR 1.1; 95% CI 1.1–1.2), and postoperative complications (OR 1.5; 95% CI 1.2–2.0). The majority of readmissions experienced a post-discharge complication.

Conclusions: Factors that span the preoperative, intraoperative, postoperative, and post-discharge phases of care were identified to increase readmission risk. To improve readmission rates, interventions will have to target factors across the surgical experience.

Introduction

Over the last decade, hospital readmissions have been increasingly viewed as a major driver of financial burden in the healthcare system. In the U.S., readmission rates are publically tracked and hospitals are penalized for high readmission rates for certain medical conditions and surgical procedures. The urgency of addressing the readmission problem extends beyond national healthcare spending to the protection of the public, as patients who are readmitted experience significantly higher morbidity.[1-3]

Radical cystectomy (RC) remains a particularly morbid operation, with approximately one in four patients being readmitted within 30 days of discharge.[4] These readmissions result in higher patient mortality, as well as significantly increased costs.[5] Little progress has been made in reducing this rate over the last decade, which has primarily been attributed to non-modifiable patient and operative factors.[6-8] Recently, the post-discharge period has become a focus of investigation and intervention.[9,10] Post-discharge complications are known to increase the risk of readmission in surgical populations. There is an increasing effort to catch them early in the outpatient setting before they lead to readmission.[11]

Of particular importance to future interventions is identification of patients at high risk for post-discharge complications and readmission. Our study used the American College of Surgeons National Quality Improvement Program (ACS NSQIP) database to explore the effect of preoperative, perioperative, and postoperative factors on post-discharge complications and readmissions in order to target quality improvement interventions.

Methods

The ACS NSQIP participant use file (PUF) captures cases from submitting hospitals in datasets that de-identify patients, hospitals, and caregivers.[12] The 2015 dataset contains infor-

mation on 30-day morbidity and mortality from 603 submitting hospitals. Data is captured from both the inpatient and outpatient settings. Using the ACS NSQIP PUF, 6400 patients undergoing RC from 2013–2015 were identified using common procedural terminology (CPT) codes for RC (51570, 51575, 51580, 51585, 51590, 51595, 51596, and 51597). Patients were included if they were ≥18 years old and had an ICD-9 or ICD-10 diagnosis code of bladder malignancy (188.x, 233.7, 239.4, C67.x, D09.0, D49.4).

Cohort selection is shown in Fig. 1. Patients with the following characteristics were excluded from the study: had disseminated cancer (n=331), transferred from another acute care hospital or urgent/emergent operation status (n=669), or were hospitalized prior to the operation (n=175). Patients were also excluded if they had a duration of operation less than 120 minutes (n=20) or a length of stay (LOS) of two days or less (n=11) and did not expire in the hospital. These likely represented aborted or aberrantly coded procedure, as the median operative time for RC has been reported around 400 minutes, while average LOS is seven days.[13,14] Patients were excluded if they had key missing data (n=15). A subgroup analysis was performed, which excluded patients with a LOS >14 days (n=722). NSQIP only tracks outcomes for 30 days from the day of the operation, and thus patients with extended LOS have a shorter post-discharge followup time.

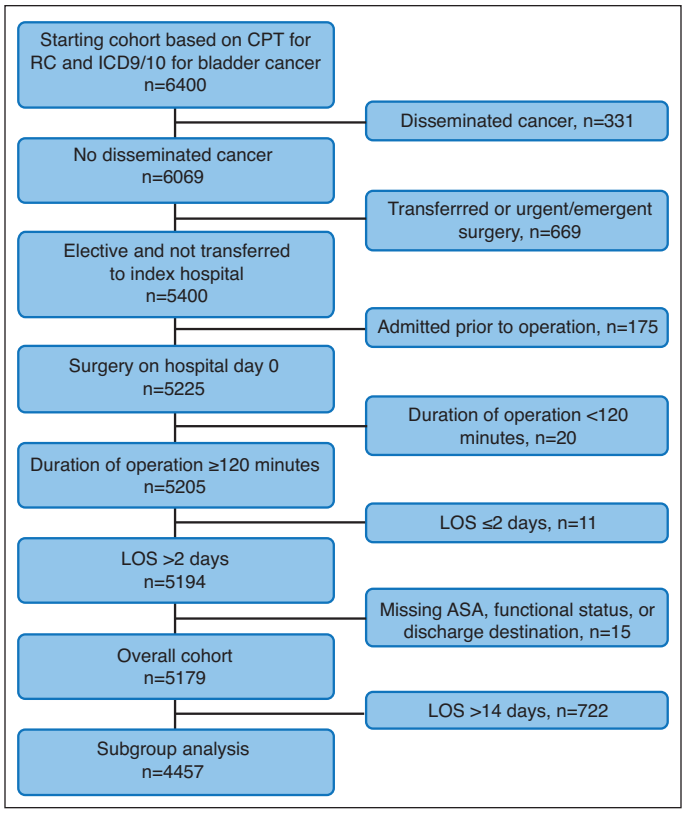

Fig. 1. Cohort selection for the subgroup analysis. ASA: American Society of Anesthesiologists; CPT: common procedural terminology; LOS: length of stay; RC: radical cystectomy.

Thus, results from the subgroup analysis were used to draw primary conclusions rather than the overall study cohort.

The primary outcome of the study was all-cause, 30-day readmission. The secondary outcomes were any post-discharge complications and major post-discharge complications. Complications were defined as the following: wound (superficial surgical site infection, deep incisional surgical site infection, organ space infection, wound disruption), sepsis (sepsis and septic shock), renal (acute renal failure and progressive renal insufficiency), venous thromboembolism (VTE) (pulmonary embolism and deep venous thrombosis), respiratory (pneumonia, unplanned reintubation, ventilation for >48 hours), stroke, urinary tract infection (UTI), cardiac (cardiac arrest requiring CPR and myocardial infarction), reoperation, and death. Minor complications were defined as superficial and deep skin and soft tissue infection (SSI), wound dehiscence, renal insufficiency, and UTI.[15] All other complications were defined as major complications. Complications were tracked from the day of the operation to the day of the reported complication. Patients that did not have their date of complication recorded were excluded from the timing analysis. The American College of Surgeons has published a new taxonomy to describe the phases of surgical care in order to facilitate the advancement of surgical quality and safety (Fig. 2).[16] We applied this taxonomy to identify opportunities for improvement. Postoperative complications were defined as taking place before or on the day of discharge, while post-discharge complications were defined as those thereafter and until 30 days after the operation.

Data on patient characteristics was collected and included sex, age, race, functional status, body mass index (BMI) (underweight <18.5 kg/m^2, normal 18.5–24.9 kg/m^2, overweight 25–29.9 kg/m^2, obese ≥30 kg/m^2), American Society of Anesthesiologists (ASA) classification, hypertension requiring medication, smoking status within a year of surgery, diabetes requiring medication, dyspnea at rest, steroid use for a chronic condition at time of surgery, history of severe chronic obstructive pulmonary disease (COPD), weight loss (>10% of body weight in six months before the operation), congestive heart failure (CHF) within 30 days of surgery, preoperative sepsis within 48 hours of surgery, and preoperative transfusion within 72 hours of surgery. Operations were classified by CPT codes and stratified into continent (51596) vs. non-continent (51570, 51575, 51580, 51585, 51590, 51595, 51597) operations.

Using the data obtained from the CPT codes, descriptive statistics were calculated. Univariate analysis was used to analyze the effect of post-discharge complications on readmission. Multivariable models using pre- and perioperative characteristics were used to assess each factor's effect on readmission, post-discharge complication, and post-discharge major complication risk. Covariates for these

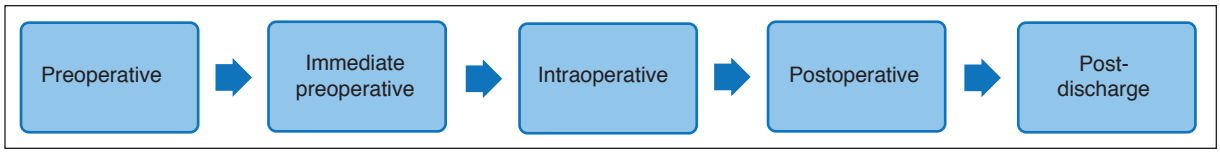

Fig. 2. American College of Surgeons surgical stages of care.[16]

models included age, sex, race, BMI, ASA score, functional status, smoking status, individual patient comorbidities, preoperative sepsis, preoperative transfusion, continent vs. non-continent urinary diversion, duration of operation in hours, wound class, LOS, and the presence of any postoperative complication. Patients who died before discharge (n=29) were excluded from the multivariable models as they could not contribute to post-discharge adverse events. All analysis was done with STATA 15.1 statistical software (STATA Corp, College Station, TX, U.S.) and tests used $p<0.05$ to determine significance. The study was deemed exempt from review by the University of Pennsylvania institutional review board (protocol 828694).

Results

Patient population

We identified 5173 patients who underwent RC between 2013 and 2015. After excluding patients with LOS >14 days, 4457 patients remained in the subgroup analysis. Major characteristics of patients stratified by those readmitted and those not readmitted are shown in Table 1 for the subgroup analysis. Full patient characteristics are shown in Supplementary Tables 1 and 2 for subgroup and overall cohorts, respectively. For the subgroup analysis, the mean age of included patients was 68.3 (standard deviation [SD] 10.2), with the majority being male (76.8%) and Caucasian

Table 1. Major patient characteristics for subgroup analysis, excluding LOS>14 days. Patients are stratified by readmission group

	Primary analysis			
		Readmission		
Variables	**Overall (%)**	**No (%)**	**Yes (%)**	**p**
Age, mean (SD)	68.3 (10.2)	68.3 (10.2)	68.3 (10.3)	0.952
Sex, male	3422 (76.8)	2731 (76.8)	691 (76.5)	0.839
Race				0.068
White	3705 (84.1)	2949 (84.3)	756 (83.7)	
Black	156 (3.5)	113 (3.2)	43 (4.8)	
Other	542 (12.3)	438 (12.5)	104 (11.5)	
BMI				<0.001
Underweight	51 (1.1)	44 (1.2)	7 (0.8)	
Normal	1134 (25.4)	963 (27.1)	171 (18.9)	
Overweight	1757 (39.4)	1383 (38.9)	374 (41.4)	
Obese	1515 (34.0)	1164 (32.8)	351 (38.9)	
Smoking	1080 (24.2)	873 (24.6)	207 (22.9)	0.304
Hypertension	2662 (59.7)	2077 (58.4)	585 (64.8)	0.001
Diabetes	871 (19.5)	654 (18.4)	217 (24.0)	<0.001
COPD	332 (7.4)	253 (7.1)	79 (8.7)	0.096
Steroid use	156 (3.5)	113 (3.2)	43 (4.8)	0.021
Bleeding disorder	140 (3.1)	101 (2.8)	39 (4.3)	0.023
Procedure type				0.004
Non-continent	3708 (83.2)	2986 (84.0)	722 (80.0)	
Continent	749 (16.8)	568 (16.0)	181 (20.0)	
Duration of operation (hours), mean (SD)	5.8 (2.0)	5.7 (1.9)	6.2 (2.0)	<0.001
LOS, mean (SD)	7.3 (2.2)	7.2 (2.2)	7.4 (2.2)	0.182
Any complication	1168 (26.2)	545 (15.3)	623 (69.0)	<0.001
Postoperative complication	409 (9.2)	304 (8.6)	105 (11.6)	0.004
Post-discharge complication	838 (18.8)	266 (7.5)	572 (63.3)	<0.001

BMI: body mass index; COPD: chronic obstructive pulmonary disease; LOS: length of stay; SD: standard deviation.

Table 2. Multivariable logistic regression of the subgroup cohort excluding LOS>14 days for factors associated with increased risk of post-discharge complications, post-discharge major complications, and readmission

	Post-discharge complications		Post-discharge major complications		Readmission	
Covariates	**OR (95% CI)**	**p**	**OR (95% CI)**	**p**	**OR (95% CI)**	**p**
Black race	–	–	–	–	1.5 (1.0–2.1)	0.044
Overweight BMI	1.4 (1.1, 1.7)	0.003	-	-	1.5 (1.2, 1.8)	<0.001
Obese BMI	1.7 (1.4, 2.2)	<0.001	1.6 (1.2, 2.1)	<0.001	1.5 (1.2, 1.9)	<0.001
Dependent functional status	2.1 (1.0–:4.1)	0.042	-	-	-	-
Hypertension	–	–	1.3 (1.0–1.6)	0.021	-	-
Diabetes	–	–	–	–	1.2 (1.0, 1.5)	0.030
COPD	1.4 (1.0, 1.9)	0.030	–	–	1.4 (1.0, 1.8)	0.041
Steroid use	-	-	–	–	1.5 (1.0–2.2)	0.034
Continent diversion	1.5 (1.2–1.8)	<0.001	1.5 (1.2–1.9)	0.002	1.4 (1.1–1.7)	0.004
Duration of operation	1.1 (1.1, 1.2)	<0.001	1.1 (1.1, 1.2)	<0.001	1.1 (1.1–1.2)	<0.001
Postoperative complications	–	–	–	–	1.5 (1.2–2.0)	0.001

–: non-significant factors. BMI: body mass index; CI: confidence interval; COPD: chronic obstructive pulmonary disease; LOS: length of stay; OR: odds ratio.

(84.1%). Other common comorbidities included hypertension (59.7%), smoking (24.2%), and diabetes (19.5%). Cystectomy with ureteroileal conduit (68.1%) was the most common procedure and 83.2% of patients underwent a non-continent procedure. Patients remained in the hospital for a mean of 7.3 days (SD 2.2) after the operation. Additionally, 26.2% of patients experienced one or more complication, with 9.2% of patients experiencing a complication postoperatively and 18.8% experiencing a complication post-discharge. The overall rate of readmission within 30 days of the operation was 20.3%.

Factors associated with readmission and post-discharge complications

Using univariable analysis, post-discharge complications were significantly associated with readmission odds ratio [OR] 21.4; 95% confidence interval [CI] 17.8–25.7; p<0.001). Multivariable analysis was performed in the subgroup and overall cohort for patient factors associated with readmission, post-discharge complications, and post-discharge major complications (Supplementary Tables 3 and 4). Significant factors for the subgroup analysis are shown in Table 2.

Characterizations of complications

Post-surgical complications and their association with readmission are displayed in Table 3 for the subgroup analysis and Supplementary Table 5 for the overall cohort. In the subgroup, major complications comprised 52.8% of all complications. The most common complications were infectious in nature, with wound (27.3%), UTIs (22.0%), and sepsis or septic shock (21.6%) making up the majority of all complications. All postoperative complications that occurred in 10 or more patients had associated readmission rates less than 50%. All individual post-discharge complication categories had readmission rates greater than 60% with the exception of patient death (35.0%). Similar to the overall complications, the most common post-discharge complications were wound (28.6%), UTIs (26.2%), and sep-

Table 3. Timing of specific postoperative complications and their associated readmission rates

Complication type	Overall (%)	Number occurring postoperative, n (%)	Readmission rate when postoperative	Number occurring post-discharge, n (%)	Readmission rate when post-discharge
Major complications	791 (17.8)	251 (5.6)	21.5	572 (12.8)	79.9
Minor complications	707 (15.9)	202 (4.5)	28.7	529 (11.9)	63.5
Wound	474 (10.6)	140 (3.1)	35.0	353 (7.9)	62.9
Sepsis	374 (8.4)	56 (1.3)	7.1	318 (7.1)	83.3
Renal	99 (2.2)	47 (1.1)	23.4	52 (1.2)	86.5
VTE	165 (3.7)	43 (1.0)	25.6	122 (2.7)	68.9
Respiratory	120 (2.7)	88 (2.0)	18.2	32 (0.7)	81.3
Urinary tract infection	381 (8.6)	51 (1.3)	20.7	323 (7.3)	72.1
Cardiac	65 (1.5)	51 (1.1)	7.8	14 (0.3)	78.6
Death	55 (1.2)	35 (0.8)	–	20 (0.5)	35.0

Complications with counts less than 10 are excluded. VTE: venous thromboembolism.

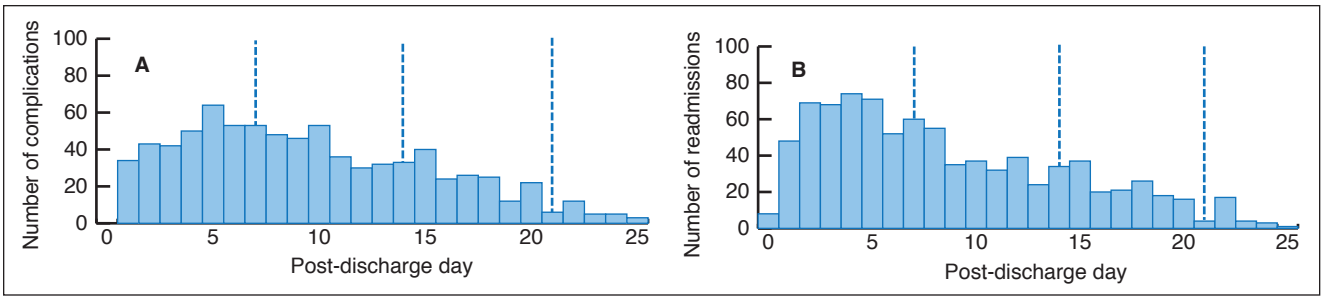

Fig. 3. Timing of ***(A)*** complications, and ***(B)*** readmissions measured from the day of discharge for the subgroup analysis. Dashed lines represent 7, 14, and 21 days post-discharge.

sis (25.8%). Of the patients who were readmitted, 63.3% experience a post-discharge complication, with 79.9% of those complications being major.

Multiple complications occurred in 24.7% of patients who experienced a complication before discharge. Meanwhile, multiple complications occurred in 43.0% of the patients who had a complication after discharge. Of the patients that had a postoperative complication, 19.3% went on to develop a post-discharge complication. Sepsis and UTIs were the most common post-discharge complications that were associated with other complications. Additionally, of the patients who developed a post-discharge UTI, 46.4% also developed sepsis.

Timing of post-discharge complications and readmission

Given their strong association with readmissions, the timing of post-discharge complications was further investigated in the subgroup analysis. Patients experienced the first complication a median of 13 days after the operation (interquartile range [IQR] 7–19) and nine days after discharge (IQR 5–14). Median time to readmission occurred 15 days after the operation (IQR 11-21 days) and 7 days (IQR 4-13 days) after discharge. Fig. 3 shows the timing of complications and readmissions from day of discharge.

Discussion

Our subgroup analysis identified 4457 patients who had undergone RC in a three-year period using the ACS NSQIP database. We found that more than a quarter of the patients experienced a postoperative or post-discharge complication and 20% required a readmission. Postoperative complications were not associated with post-discharge complications. Infections were the most common complication requiring readmission. Preoperative (BMI, diabetes, COPD, and steroid use), intraoperative (operative duration), postoperative (complications), and post-discharge (complications) factors were associated with the likelihood of readmission. Based on the study results, actionable targets for improvement may exist in the preoperative and post-discharge phases.

Readmission rates in prior studies range from 19.7–28.5%, which is consistent with our rate of 20.3%.[17-20] We found multiple patient comorbidities that predicted readmission. Previous papers have used composite comorbidity or frailty scores in risk adjustment.[6,15,21] This is the first study to demonstrate the important association of each independent risk factors with readmissions in the cystectomy population. Given the different medical and social factors surrounding each individual comorbidity, we hypothesized that some might contribute to readmission risk more than others. In so doing, we identified increasing BMI, diabetes, COPD, and steroid use as independent predictors of readmission, providing evidence that optimizing pre-surgical management of these conditions may reduce risk. Elements of the American College of Surgeons *Strong for Surgery* campaign may be useful in the mitigation of several of these risk factors.[22] The campaign's physician toolkit specifically targets preoperative nutritional status, smoking cessation, glycemic control, and medication use through standardization of preoperative risk assessment and patient engagement. Based on our results, interventions such as identifying and beginning treatment in patients with undiagnosed diabetes and tapering steroid doses may lead to decreased readmission rates. However, time to cystectomy must not be delayed in order to preserve oncological outcomes.

Each of the identified risk factors is known to impair immunity and increase the odds of infections.[23-25] As infectious complications were most common among readmissions, improved management of these risk factors and perioperative infection control would likely reduce the occurrence rate. Antimicrobial prophylaxis and good surgical technique should always be followed perioperatively, however, protocols for prophylaxis after RC remain under debate. Recently, Pariser et al[26] modified the protocol at their institution using existing culture data. They found that broadening antimicrobial coverage from cefoxitin to ampicillin-sulbactam, gentamicin, and fluconazole decreased their infection rate by 11%. Targeting prophylaxis based on previous data provides one avenue where institutions may decrease their infection rates while minimizing the risk of exposing patients to drug-resistant organisms. A recent study

of the NSQIP database found that women are at increased risk of SSI following RC.[27] Our multivariable analysis controlled for sex, and thus we believe our outcomes are applicable to women. However, we did not stratify post-discharge complications by category, which explains the differences in our results.

Post-discharge home services, which have been shown to reduce readmission rates in some settings, may be useful in this population as well.[28,29] Innovative programs may prove to be beneficial in these high-risk surgical patients. Specifically, the "discharge to assess" program has shown promise in elderly populations and could be transitioned to other populations.[30] This program has moved the formal discharge to the patient's home, after the transition out of the hospital, in order to assess the needs in the patient's own home and ensure a viable discharge plan is actualized. Close followup is also warranted in this population. With a mathematical model, Krishnan et al[9] demonstrated that an office visit at day 4 or 5 post-discharge has the greatest chance at preventing readmission. However, they used fixed probability for detecting complications by office visit or telephone and there has not been a published series implementing early office visits for RC.

Risk scores to predict readmission might be of use to identify patients that require increased or altered post-discharge care. The only risk score that exists for adverse events after RC is the ACS NSQIP risk calculator, which was created based on aggregate NSQIP data across all surgical procedures.[31] However, it commonly under-predicts outcomes after RC.[32] Studies have suggested that patient characteristics do not predict readmission in a reliable fashion, and prospective studies would require large sample sizes to create and validate such tools.[17,19,33] Using the results of our multivariable analysis, we attempted to build and validate a nomogram and risk score for readmission. However, we also found that using patient and operative characteristics led to poor prediction of readmission. It is likely that variables not captured in NSQIP, such as prior abdominal surgery, radiation, chemotherapy, socio-economic status, and distance to index hospital, need to be included to accurately predict readmission risk.

Our study demonstrates patterns of care that are consistent with other studies. Similar to our findings, Sood et al found that patients with postoperative complications have an increased risk of readmission.[14] Our study builds on this evidence using a larger patient cohort and examining the association between postoperative and post-discharge complications as a potential explanation for readmissions. This allowed us to test, and subsequently find no association, between postoperative complications and post-discharge complications. Our study adds to the existing literature on readmissions in defining the distinction between postoperative and post-discharge complications. It identifies factors to serve as targets for quality improvement and matches these factors to the phases of care and programs that exist in order to encourage readers to address these issues in the local care setting. Strategies to prevent readmission should then be shared with the urological community, as published series describing methods to reduce readmission after RC are currently lacking in the literature.

There are several limitations to our study. ACS NSQIP only collects data from participating institutions, and thus may miss some cystectomies performed in this time period. Differences between institutions that participate in data collection and those that don't might influence our results. NSQIP is de-identified at the patient, surgeon, and hospital level; therefore, we cannot account for factors such as surgeon experience and hospital volume, which may have an effect on results (such as complication rate). While patient comorbidities were noted to increase the risk of readmission, it is unclear the preoperative severity of these comorbidities or how many of these patients had optimized medical management of their conditions prior to surgery. Certain factors, such as neoadjuvant chemotherapy, use of laparoscopic or robotic-assistance, and other outcomes, such as anastomotic leak, are not collected and are often of interest when examining cystectomy populations. Because outcomes are only collected 30 days after the operation, patients with longer LOS have fewer days to present with post-discharge complications and be captured by the database. We attempted to minimize this bias by excluding patients with lengths of stay greater than 14 days in the subgroup analysis. However, doing so likely underestimates the incidence of adverse events in this population. Thus, we included an analysis of the full cohort in the supplementary section. Our study specifically examined early complications following RC. Thus, we likely underestimated the total amount of adverse events that occur after RC with extended postoperative followup. While complications were stratified by major and minor, NSQIP does not collect information on Clavien-Dindo grade.

Complications within each category may be heterogeneous. Additionally, the median time to complication was shorter than the median time to readmission in our study. Caution must be used when interpreting the timing of adverse events in NSQIP. Complications may only be identified and recorded on readmission, even if they had occurred sooner. Finally, factors such as tumor stage, socioeconomic status, insurance status, and distance to index hospital are not collected by ACS NSQIP and have been shown to affect readmission rates.[5]

Conclusions

Over 20% patients are readmitted following RC. Risk is influenced by factors that span the surgical experience. Opportunity exist to improve readmission rates, however, interventions must collectively target the preoperative,

intraoperative, postoperative, and post-discharge phases of care. Multifaceted approaches may reduce the burden of readmissions in this population.

Competing interests: The authors report no competing personal or financial interests related to this work.

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This paper has been peer-reviewed.

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Supplementary Table 1. Full patient characteristics for the subgroup analysis excluding patients with a LOS >14 days

		Readmission		
Variables	**Overall (%)**	**No (%)**	**Yes (%)**	**p**
Age, mean (SD)	68.3 (10.2)	68.3 (10.2)	68.3 (10.3)	0.952
Sex, male	3422 (76.8)	2731 (76.8)	691 (76.5)	0.839
Race				0.068
White	3705 (84.1)	2949 (84.3)	756 (83.7)	
Black	156 (3.5)	113 (3.2)	43 (4.8)	
Other	542 (12.3)	438 (12.5)	104 (11.5)	
BMI				**<0.001**
Underweight	**51 (1.1)**	**44 (1.2)**	**7 (0.8)**	
Normal	**1134 (25.4)**	**963 (27.1)**	**171 (18.9)**	
Overweight	**1757 (39.4)**	**1383 (38.9)**	**374 (41.4)**	
Obese	**1515 (34.0)**	**1164 (32.8)**	**351 (38.9)**	
ASA class				0.125
No disturb	1194 (26.8)	975 (27.4)	219 (24.3)	
Mild disturb	3075 (69.0)	2434 (68.5)	641 (71.0)	
Severe disturb	188 (4.2)	145 (4.1)	43 (4.8)	
Functional status				0.383
Independent	4414 (99.0)	3,522 (99.1)	892 (98.8)	
Dependent	43 (1.0)	32 (0.9)	11 (1.2)	
Smoking	1080 (24.2)	873 (24.6)	207 (22.9)	0.304
Hypertension	**2662 (59.7)**	**2077 (58.4)**	**585 (64.8)**	**0.001**
Diabetes	**871 (19.5)**	**654 (18.4)**	**217 (24.0)**	**<0.001**
Dyspnea	357 (8.0)	284 (8.0)	73 (8.1)	0.927
COPD	332 (7.4)	253 (7.1)	79 (8.7)	0.096
CHF	23 (0.5)	16 (0.5)	7 (0.8)	0.224
Steroid use	**156 (3.5)**	**113 (3.2)**	**43 (4.8)**	**0.021**
Weight loss	94 (2.1)	74 (2.1)	20 (2.2)	0.804
Bleeding disorder	**140 (3.1)**	**101 (2.8)**	**39 (4.3)**	**0.023**
Preoperative transfusion	16 (0.4)	14 (0.4)	2 (0.2)	0.439
Preoperative SIRS/sepsis	24 (0.5)	20 (0.6)	4 (0.4)	0.661
Procedure type				0.004
Non-continent	**3708 (83.2)**	**2986 (84.0)**	**722 (80.0)**	
Continent	**749 (16.8)**	**568 (16.0)**	**181 (20.0)**	
Duration of operation (hours), mean (SD)	**5.8 (2.0)**	**5.7 (1.9)**	**6.2 (2.0)**	**<0.001**
Length of stay (days), mean (SD)	7.3 (2.2)	7.2 (2.2)	7.4 (2.2)	0.182
Wound classification				0.683
Clean	69 (1.6)	58 (1.6)	11 (1.2)	
Clean/contaminated	4154 (93.2)	3310 (93.1)	844 (93.4)	
Contaminated	218 (4.9)	172 (4.8)	46 (5.1)	
Dirty	16 (0.4)	14 (0.4)	2 (0.2)	
Any complication	**1168 (26.2)**	**545 (15.3)**	**623 (69.0)**	**<0.001**
Postoperative complication	**409 (9.2)**	**304 (8.6)**	**105 (11.6)**	**0.004**
Post-discharge complication	**838 (18.8)**	**266 (7.5)**	**572 (63.3)**	**<0.001**

Patients are stratified by readmission. ASA: American Society of Anesthesiologists; BMI: body mass index; CHF: congestive heart failure; COPD: chronic obstructive pulmonary disease; LOS: length of stay; SIRS: systemic inflammatory response syndrome; SD: standard deviation

Supplementary Table 2. Full patient characteristics for the overall cohort stratified by readmission

		Readmission		
Variables	**Overall (%)**	**No (%)**	**Yes (%)**	**P**
Age, mean (SD)	68.6 (10.2)	68.6 (10.1)	68.5 (10.3)	0.904
Sex, male	3980 (76.8)	3228 (76.9)	752 (76.8)	0.977
Race				0.081
White	4235 (82.8)	3424 (82.8)	811 (82.8)	
Black	194 (3.8)	146 (3.5)	48 (4.9)	
Other	683 (13.4)	563 (13.6)	120 (12.3)	
BMI				**<0.001**
Underweight	**64 (1.2)**	**52 (1.2)**	**12 (1.2)**	
Normal	**1307 (25.2)**	**1125 (26.8)**	**182 (18.6)**	
Overweight	**2025 (39.1)**	**1624 (38.7)**	**401 (41.0)**	
Obese	**1783 (34.4)**	**1399 (33.3)**	**384 (39.2)**	
ASA class				0.340
No disturb	1355 (26.2)	1117 (26.6)	238 (24.3)	
Mild disturb	3580 (69.1)	2887 (68.7)	693 (70.8)	
Severe disturb	244 (4.7)	196 (4.7)	48 (4.9)	
Functional status				0.835
Independent	5124 (98.9)	4156 (99.0)	968 (98.9)	
Dependent	55 (1.1)	44 (1.0)	11 (1.1)	
Smoking	1244 (24.0)	1021 (24.3)	223 (22.8)	0.313
Hypertension	**3137 (60.6)**	**2501 (59.5)**	**636 (65.0)**	**0.002**
Diabetes	**1032 (19.9)**	**797 (19.0)**	**235 (24.0)**	**<0.001**
Dyspnea	444 (8.6)	358 (8.5)	86 (8.8)	0.793
COPD	409 (7.9)	320 (7.6)	89 (9.1)	0.124
CHF	30 (0.6)	23 (0.5)	7 (0.7)	0.534
Steroid use	**183 (3.5)**	**137 (3.3)**	**46 (4.7)**	**0.028**
Weight loss	117 (2.3)	91 (2.2)	26 (2.7)	0.354
Bleeding disorder	174 (3.4)	132 (3.1)	42 (4.3)	0.073
Preoperative transfusion	19 (0.4)	17 (0.4)	2 (0.2)	0.350
Preoperative SIRS/sepsis	33 (0.6)	29 (0.7)	4 (0.4)	0.318
Procedure type				0.023
Non-continent	**4301 (83.1)**	**3512 (83.6)**	**789 (80.6)**	
Continent	**878 (17.0)**	**688 (16.4)**	**190 (19.4)**	
Duration of operation (hours), mean (SD)	**5.9 (2.0)**	**5.8 (2.0)**	**6.2 (2.0)**	**<0.001**
LOS (days), mean (SD)	**9.4 (7.0)**	**9.7 (7.5)**	**8.1 (3.5)**	**<0.001**
Wound classification				0.504
Clean	81 (1.6)	70 (1.7)	11 (1.1)	
Clean/contaminated	4832 (93.3)	3915 (93.2)	917 (93.7)	
Contaminated	248 (4.8)	199 (4.7)	49 (5.0)	
Dirty	18 (0.4)	16 (0.4)	2 (0.2)	
Any complication	**1665 (32.1)**	**965 (23.5)**	**680 ((69.5)**	**<0.001**
Postoperative complication	877 (16.9)	731 (17.4)	146 (14.9)	0.061
Post-discharge complication	**896 (17.3)**	**292 (7.0)**	**604 (61.7)**	**<0.001**

ASA: American Society of Anesthesiologists; BMI: body mass index; CHF: congestive heart failure; COPD: chronic obstructive pulmonary disease; LOS: length of stay; SIRS: systemic inflammatory response syndrome; SD: standard deviation.

Supplementary Table 3. Multivariable regression for the subgroup analysis excluding patients with LOS >14 days of post-discharge complications, post-discharge major complications, and readmission

Covariates	Post-discharge complications		Post-discharge major complications		Readmission	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Age	1.00 (0.99–1.01)	0.882	1.01 (0.99–1.02)	0.307	1.01 (1.00–1.01)	0.065
Sex, male						
Male	Reference	–	Reference	–	Reference	–
Female	1.07 (0.89–1.29)	0.491	1.01 (0.81–1.26)	0.930	1.09 (0.91–1.31)	0.344
Race						
White	Reference	–	Reference	–	Reference	–
Black	0.92 (0.60–1.41)	0.702	0.93 (0.57–1.54)	0.791	**1.47 (1.01–2.13)**	**0.044**
Other	0.83 (0.64–1.08)	0.165	0.87 (0.64–1.19)	0.388	1.09 (0.86–1.38)	0.492
BMI						
Normal	Reference	–	Reference	-	Reference	–
Underweight	1.46 (0.70–3.05)	0.311	1.52 (0.65–3.52)	0.334	0.86 (0.37–1.99)	0.732
Overweight	**1.38 (1.11–1.72)**	**0.003**	1.22 (0.95–1.57)	0.122	**1.48 (1.21–1.82)**	**<0.001**
Obese	**1.73 (1.39–2.17)**	**<0.001**	**1.60 (1.23–2.07)**	**<0.001**	**1.51 (1.21–1.87)**	**<0.001**
ASA class						
No disturb	Reference	–	Reference	–	Reference	–
Mild disturb	1.05 (0.88–1.27)	0.582	0.94 (0.76–1.17)	0.588	1.07 (0.89–1.28)	0.461
Severe disturb	1.02 (0.67–1.57)	0.910	0.99 (0.61–1.60)	0.958	1.18 (0.79–1.75)	0.411
Functional status						
Independent	Reference	–	Reference	–	Reference	–
Dependent	**2.05 (1.03–4.08)**	**0.042**	1.98 (0.90–4.38)	0.089	1.55 (0.76–3.14)	0.225
Smoking	0.99 (0.81–1.20)	0.890	1.00 (0.80–1.25)	0.991	0.98 (0.81–1.18)	0.796
Hypertension	1.15 (0.96–1.35)	0.120	**1.27 (1.04–1.56)**	**0.021**	1.15 (0.97–1.36)	0.102
Diabetes	1.05 (0.86–1.28)	0.631	1.02 (0.81–1.28)	0.867	**1.23 (1.02–1.49)**	**0.030**
Dyspnea	0.89 (0.66–1.20)	0.434	0.84 (0.59–1.20)	0.333	0.84 (0.62–1.13)	0.245
COPD	**1.40 (1.03–1.89)**	**0.030**	1.39 (0.98–1.97)	0.063	**1.36 (1.01–1.82)**	**0.041**
CHF	1.02 (0.37–2.83)	0.975	1.15 (0.37–3.52)	0.811	1.25 (0.49–3.16)	0.638
Steroid use	1.11 (0.74–1.68)	0.608	1.05 (0.65–1.70)	0.844	**1.50 (1.03–2.18)**	**0.034**
Weight loss	1.53 (0.93–2.52)	0.092	1.03 (0.55–1.95)	0.915	1.17 (0.70–1.96)	0.548
Bleeding disorder	1.15 (0.76–1.75)	0.515	1.25 (0.78–2.00)	0.361	1.43 (0.97–2.11)	0.069
Preoperative Transfusion	1.27 (0.35–4.59)	0.713	0.58 (0.07–4.45)	0.599	0.59 (0.13–2.69)	0.494
Preoperative SIRS/sepsis	1.16 (0.42–3.21)	0.773	1.54 (0.51–4.67)	0.443	0.77 (0.25–2.34)	0.644
Procedure type						
Non-continent	Reference	–	Reference	–	Reference	–
Continent	**1.46 (1.18–1.79)**	**<0.001**	**1.47 (1.16–1.86)**	**0.002**	**1.35 (1.10–1.66)**	**0.004**
Duration of operation (hours)	**1.12 (1.07–1.16)**	**<0.001**	**1.14 (1.09–1.20)**	**<0.001**	**1.11 (1.07–1.16)**	**<0.001**
Wound classification						
Clean	Reference	–	Reference	–	Reference	–
Clean contaminated	1.51 (0.74–3.10)	0.258	0.95 (0.46–1.94)	0.878	1.33 (0.69–2.57)	0.397
Contaminated	0.91 (0.40–2.05)	0.821	0.58 (0.25–1.35)	0.206	1.29 (0.62–2.69)	0.499
Dirty	0.81 (0.15–4.29)	0.803	0.76 (0.14–4.09)	0.749	0.57 (0.11–2.99)	0.509
LOS (days)	1.00 (0.96–1.04)	0.877	0.99 (0.91–1.70)	0.652	0.99 (0.96–1.03)	0.669
Postoperative complication	1.09 (0.82–1.44)	0.549	1.25 (0.91–1.70)	0.169	**1.52 (1.17–1.96)**	**0.001**

ASA: American Society of Anesthesiologists; BMI: body mass index; CHF: congestive heart failure; CI: confidence interval; COPD: chronic obstructive pulmonary disease; LOS: length of stay; OR: odds ratio; SIRS: systemic inflammatory response syndrome; SD: standard deviation.

Supplementary Table 4. Multivariable regression for the overall cohort of post-discharge complications, post-discharge major complications, and readmission

Covariates	Post-discharge complications		Post-discharge major complications		Readmission	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Age	1.00 (0.99–1.01)	0.996	1.01 (1.00–1.02)	0.147	**1.01 (1.00–1.02)**	**0.017**
Sex, male						
Male	Reference	–	Reference	–	Reference	–
Female	1.07 (0.89–1.28)	0.486	1.02 (0.82–1.26)	0.881	1.06 (0.89–1.26)	0.502
Race						
White	Reference	–	Reference	–	Reference	–
Black	0.81 (0.53–1.23)	0.322	0.84 (0.52–1.38)	0.503	**1.47 (1.04–2.09)**	**0.029**
Other	0.89 (0.69–1.13)	0.341	0.90 (0.67–1.21)	0.496	1.16 (0.93–1.44)	0.202
BMI						
Normal	Reference	–	Reference	–	Reference	–
Underweight	1.72 (0.88–3.39)	0.113	1.72 (0.78–3.78)	0.180	1.55 (0.79–3.04)	0.198
Overweight	**1.40 (1.13–1.72)**	**0.002**	1.24 (0.97–1.58)	0.092	**1.50 (1.23–1.83)**	**<0.001**
Obese	**1.75 (1.41–2.17)**	**<0.001**	**1.62 (1.26–2.08)**	**<0.001**	**1.56 (1.27–1.92)**	**<0.001**
ASA class						
No disturb	Reference	–	Reference	–	Reference	–
Mild disturb	1.02 (0.86–1.22)	0.809	0.91 (0.74–1.12)	0.393	1.05 (0.89–1.25)	0.564
Severe disturb	1.12 (0.76–1.67)	0.556	1.02 (0.64–1.60)	0.943	1.14 (0.79–1.66)	0.475
Functional status						
Independent	Reference	–	Reference	–	Reference	–
Dependent	**1.97 (1.02–3.80)**	**0.042**	1.80 (0.82–3.92)	0.140	1.30 (0.65–2.59)	0.457
Smoking	0.99 (0.82–1.19)	0.874	1.00 (0.80–1.25)	0.973	0.97 (0.81–1.16)	0.739
Hypertension	1.13 (0.96–1.34)	0.137	**1.25 (1.03–1.52)**	**0.026**	1.11 (0.95–1.31)	0.196
Diabetes	1.03 (0.85–1.25)	0.736	1.00 (0.80–1.25)	0.978	**1.22 (1.02–1.45)**	**0.032**
Dyspnea	1.01 (0.76–1.34)	0.940	0.87 (0.62–1.22)	0.415	0.89 (0.67–1.16)	0.381
COPD	**1.41 (1.06–1.88)**	**0.018**	1.37 (0.98–1.92)	0.064	**1.38 (1.04–1.81)**	**0.023**
CHF	0.79 (0.29–2.12)	0.632	0.99 (0.33–2.94)	0.981	0.98 (0.41–2.36)	0.967
Steroid use	1.16 (0.79–1.72)	0.447	1.13 (0.71–1.80)	0.597	**1.48 (1.04–2.11)**	**0.031**
Weight loss	1.56 (0.97–2.49)	0.065	1.09 (0.60–2.00)	0.770	1.48 (0.93–2.34)	0.098
Bleeding disorder	1.15 (0.77–1.72)	0.482	1.19 (0.75–1.89)	0.449	1.35 (0.93–1.94)	0.110
Preoperative transfusion	1.14 (0.32–4.09)	0.826	0.53 (0.07–4.05)	0.540	0.52 (0.12–2.32)	0.391
Pre-operative SIRS/sepsis	0.90 (0.33–2.43)	0.834	1.25 (0.42–3.69)	0.689	0.60 (0.20–1.78)	0.358
Procedure type						
Non-continent	Reference	–	Reference	–	Reference	–
Continent	**1.44 (1.18–1.75)**	**<0.001**	**1.46 (1.16–1.84)**	**0.001**	**1.30 (1.07–1.58)**	**0.009**
Duration of operation (hours)	**1.11 (1.07–1.16)**	**<0.001**	**1.14 (1.09–1.19)**	**<0.001**	**1.11 (1.07–1.15)**	**<0.001**
Wound classification						
Clean	Reference	–	Reference	–	Reference	–
Clean contaminated	1.70 (0.83–3.44)	0.144	1.04 (0.51–2.12)	0.914	1.50 (0.78–2.87)	0.221
Contaminated	1.01 (0.45–2.25)	0.987	0.65 (0.28–1.52)	0.320	1.46 (0.71–3.01)	0.301
Dirty	1.02 (0.20–5.35)	0.977	0.95 (0.18–5.04)	0.956	0.73 (0.14–3.73)	0.708
LOS (days)	**0.94 (0.92–0.96)**	**<0.001**	**0.93 (0.90–0.95)**	**<0.001**	**0.93 (0.91–0.95)**	**<0.001**
Postoperative complication	0.99 (0.76–1.28)	0.933	1.15 (0.86–1.55)	0.353	**1.39 (1.10–1.76)**	**0.005**

ASA: American Society of Anesthesiologists; BMI: body mass index; CHF: congestive heart failure; CI: confidence interval; COPD: chronic obstructive pulmonary disease; LOS: length of stay; OR: odds ratio; SIRS: systemic inflammatory response syndrome; SD: standard deviation.

Supplementary Table 5. Timing of specific postoperative complications in the overall cohort and their associated readmission rates

Complication type	Overall (%)	Number occurring postoperative, n (%)	Readmission rate when postoperative	Number occurring post-discharge, n (%)	Readmission rate when post-discharge
Major complications	1213 (23.4)	655 (12.7)	13.6	604 (11.7)	79.0
Minor complications	989 (19.1)	452 (8.7)	16.8	567 (11.0)	62.8
Wound	755 (14.6)	397 (7.7)	16.6	380 (7.3)	61.8
Sepsis	597 (11.5)	263 (5.1)	5.3	335 (6.5)	83.0
Renal	168 (3.2)	114 (2.2)	12.3	54 (1.0)	87.0
VTE	237 (4.6)	111 (2.1)	14.4	126 (2.4)	66.7
Respiratory	259 (5.0)	223 (4.3)	9.0	36 (0.7)	83.3
Urinary tract infection	481 (9.3)	143 (2.8)	12.6	338 (6.5)	71.9
Cardiac	105 (2.0)	91 (1.8)	11.0	14 (0.3)	78.6
Death	83 (1.6)	62 (1.2)	–	21 (0.4)	33.3

VTE: venous thromboembolism.