Open versus Robot-Assisted Radical Cystectomy: 30-day Perioperative Comparison and Predictors for Complication, Readmission, and Cost-to-patient Charges

By

Jason Flamiatos

THESIS

Presented to the School of Public Health and Oregon Health & Science University in partial fulfillment of the requirements for the degree of Master of Public Health

May 31, 2017

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

CCD	Continent Cutaneous Diversion
CCI	Charlson Comorbidity Index
CCS	Charlson Comorbidity Score
EBL	Estimated Blood Loss
IC	Ileal Conduit
LOS	Length of Stay
NB	Neobladder
ORC	Open Radical Cystectomy
RARC	Robotic-Assisted Radical Cystectomy

ACKNOWLEDGEMENTS

The generosity of knowledge, time, and patience from so many mentors and colleagues deserve endless gratitude from me. I am honored to have been surrounded by so many remarkable individuals and teams of people that have helped me throughout my medical and public health education.

To Dr. Amling, thank you for your invaluable mentorship in shaping my career as a urologist. Your enthusiasm to undertake this thesis journey with me enriched my ambition to pursue quality work both as a urologist and researcher. To Ann Martinez Acevedo, Susi Driscoll, and the entire OHSU Department of Urology, thank you for the nonstop support in helping me be successful.

To Dr. Garzotto, you were the first urologist to take me under your wing and introduce me to research methods, statistics, and the field of urologic surgery. Without your willingness and excitement to work with me for so many years, I would not be where I am today.

To Dr. Becker, thank you for your always helpful and comical critiques throughout my thesis development ensuring the final project was done on-time and well. Your guidance and experience were invaluable in allowing me to see the forest rather than getting lost in the trees.

To Dr. Lambert, I appreciate all of your wisdom bestowed upon me during my initial writing of my thesis proposal. Your excellent and frequent feedback drove me to develop a very complete proposal early on that allowed me to be productive and efficient in the later stages of my thesis completion. I am so fortunate that you joined my committee and forever challenge me to look at the world in new ways.

To Dr. Chen, thank you for your patience and expertise helping me through the depths of biostatistics pertaining to my project. Your analytical skills and perspective allowed me to see data more clearly with

defined goals and objectives. Replying quickly to my frantic emails on Saturday evenings always comforted the statistically significant stress I experienced at times wading through Stata! :)

To Dr. Stull, since my first day as an MD/MPH student at OHSU, you have guided me and my fellow MD/MPH classmates on a journey to open our minds, re-create the way we view the world, and to be thought leaders in our lives ahead.

And lastly, I am thankful and indebted to my family and my fellow MD/MPH classmates, who are now family as well. You've made the journey not only fun and enjoyable these past five years, but bestowed upon me endless support and friendship.

ABSTRACT

Introduction: Bladder cancer is a costly cancer to manage with high post-operative morbidity and readmission frequencies. Clinical benefits of robotic-assisted radical cystectomy (RARC) suggest that it may be a reasonable and appealing alternative to traditional open radical cystectomy (ORC). However, limited data exist regarding complication, readmission, and cost comparisons between the two approaches. Our two research questions for this study were: (1) During the 30-day perioperative period, does robotic-assisted radical cystectomy demonstrate cost-to-patient savings, reduced complications, and reduced readmissions compared to the open approach? (2) What predicts complication, readmission, or total cost-to-patient following robotic or open cystectomy?

Methods: We conducted a retrospective cohort study comparing open (n=149) versus robotic (n=100) cystectomy in patients who underwent surgery between 2009 and 2015 at our institution. Primary outcomes were assessed from time of surgery to 30-days post-operatively: (1) complication, (2) readmission, and (3) total cost-to-patient charge. Clavien-Dindo/MSKCC classifications were used for complication grading and categorization. Hospital amortization and maintenance costs of the robot were not included so as to directly compare surgical approach only in the 30-day perioperative period. Multivariable logistic and linear regression models were used.

Results: Patient, clinical and surgical characteristics were mostly similar between open and robotic groups, except for median estimated blood loss (600 versus 150 cc, p<0.01), operative time (6.19 versus 6.85 hrs, p<0.01), and median length of stay (7 versus 5 days, p<0.01), respectively.

Complication: The frequency of patients with at least one 30-day complication was 86% for open compared to 66% for robotic (p<0.01). Minor gastrointestinal and bleeding complications were significantly increased in the open group compared to robotic (50% vs 41%, p=0.01; 52% vs 11%, p<0.01, respectively). Fifty percent of open patients required blood transfusion compared to only 11% in the robotic group (p<0.01). Patients in the open group had significantly more major complications (19%) compared to the robotic group (10%) (p=0.04). When controlling for other covariates, robotic approach was a significant predictor for having lower odds of at least one 30-day complication (OR 0.44, p=0.049, 95% CI 0.20-0.99).

Readmission: There was no significant difference in number of patients readmitted at least one time in open (31%) compared to robotic cystectomy (27%) (p=0.51). Surgical approach was not a significant predictor of 30-day readmission.

Cost: Median total cost-to-patient was significantly reduced in the robotic group versus open ($57336 versus $69976, p<0.01). The robotic approach was a significant predictor of reduced total cost-to-patient compared to open approach (18% reduction, p<0.01) when considering all 30-day perioperative charges.

Conclusion: RARC is associated with fewer gastrointestinal and blood loss complications relative to ORC. When comparing 30-day post-operative cost-to-patient charges, robotic cystectomy demonstrates a reduced total cost compared to open cystectomy. Our findings do not directly include amortization and maintenance costs of the robot, thus more closely simulating the true costs when amortization is actually completed. Coupling this with taking into account 30-day complications and service costs, robotic cystectomy may truly reach a point of reduced overall cost-to-patient relative to ORC.

INTRODUCTION

The application and utilization of robotics during cystectomy for bladder cancer treatment are still being defined as information of cost and clinical outcomes are needed.[1] Bladder cancer is the tenth most common cancer in the U.S. and the fourth most common in men.[2, 3] Approximately 74,000 new cases are diagnosed in the U.S. each year.[3] For those over the age of 79 years, it is one of the top five causes of cancer deaths.[3] The cost of managing this disease remains one of the most expensive cancers for patients and health systems that can top $30,000 for the operative period alone.[4, 5] One factor contributing to high cost is readmission secondary to complications after cystectomy.[6-8] This is not only burdensome and frightening to the patient, but it is also extremely costly for patients and health systems.

Open radical cystectomy (ORC) is the current standard of care for definitive surgical treatment of bladder cancer, but the prevalence of robotic-assisted radical cystectomy (RARC) has grown in the past decade.[9] It remains poorly understood how the costs associated with the short- and long-term clinical benefits of RARC versus ORC actually compare. This leaves clinicians, patients, institutions and policy makers shrouded in doubt about which method is best regarding both complications and cost. Until this information is elucidated, our ability to conclusively decide whether RARC should be adopted as the new standard of care remains hindered. However, some recent data suggest that RARC offers unique cost savings with a reduced number of minor complications and shorter hospital stays compared to ORC.[10] Amidst the evolving health system, limited resources, and a growing insured and aging population, further exploration of which cystectomy approach, risk factors, and other modifiable targets can reduce cost, maintain or improve population health, and enhance patient experience.

This study aimed to compare the following between ORC and RARC: (1) 30-day complication and readmission frequencies, and (2) cost-to-patient (charge) taking into account all services rendered from time of time of surgery to 30-days post-operatively.

Our study results inform financial and clinical comparisons between the current standard of care and the newest adopted technology. The robust combination of clinical and cost-to-patient data make our study unique, especially for Oregon and similar institutions. Ultimately, as health care strives for efficient utilization of resources, policy makers, institutions, clinicians, and patients seek the answers sought in this study to responsibly use limited finances and improve health and experience for our patients.

From a public health perspective, given the high number of incident cases annually, cost savings from implementing a financially favorable surgical approach in the right regional setting could provide substantive savings over time. For the health system, reduced spending on complications and readmissions related to a particular operative method may have meaningful financial impact, as well. Patients with bladder cancer may make informed decisions with their clinicians when choosing cystectomy approach based upon which approach may have lower likelihood of complication, readmission, and cost.

PATIENTS AND METHODS

Study Design

This retrospective cohort study compares complication and readmission frequencies in addition to cost-to-patient of robotic-assisted radical cystectomy (RARC) versus open radical cystectomy (ORC).

Patients and Data Source

We used an institutional database compiled from electronic medical records of all patients who underwent either RARC (n=100) or ORC (n=149) for muscle-invasive bladder cancer from January 2009 to December 2015 at Oregon Health and Science University (OHSU). This clinical database was then combined with cost-to-patient charge data available from the OHSU Billing Department (Figure 1). Patients chose their surgical approach based upon personal preference as the indications for pursuing either ORC or RARC are identical.[11] Based upon the preferred approach by each patient, they sought care from either of two available urologic oncologists. One surgeon of three performed 98% of all robotic cystectomies, while two of six surgeons performed 94% of all open cystectomies. All analyzable patients underwent cancer-related cystectomy and lymph node dissection. Patients excluded from analyses had partial cystectomies, other concurrent procedures (i.e., partial cystectomy, cystectomy with nephrectomy/nephroureterectomy/sigmoidoscopy, etc.). Data abstractors were blinded to the study outcomes.

Regulatory and Ethics

This study did not involve any contact with patients as we used an existing repository assembled from patient medical records with OHSU Institutional Review Board (IRB) approval (IRB00010437). Because this was a secondary data analysis, a waiver of consent was obtained from the IRB for all patients as standard of care upon receiving care at OHSU.

Measurements

Primary Exposure and Outcomes

The primary exposure is cystectomy approach: open radical cystectomy or robotic-assisted radical cystectomy.

Primary outcomes are: (1) development of at least one cystectomy-related complication within 30-days post-surgery, (2) development of at least one cystectomy-related hospital readmission within 30-days post-surgery, and (3) overall and service-specific category cost-to-patient charges from time of surgery to 30-days post-operatively.

Surgery Specifics

Patients in both groups underwent radical cystectomy with bilateral pelvic lymphadenectomy to the level of common iliac arteries whenever possible, followed by urinary diversion (ileal conduit (IC), neobladder (NB), or continent cutaneous diversion (CCD)).

Pre-operative Characteristics and Comorbidities as Covariates

Patient demographics include age, gender, race, urban/rural, and associated comorbidities.[12] Pre-operative comorbidity is quantified using the Charlson Comorbidity Index (CCI) that is age-adjusted, making it the Charlson Comorbidity Score (CCS) (See Appendix Table A).[13] Note that only malignancies in addition to bladder cancer diagnosed and treated within 5 years, not incidental prostate cancer found after cystoprostatectomy, were factored into the CCS for all patients.

Post-operative Complication Grading and Classification

It is important to recognize that marked variability exists between previously reported post-cystectomy complication frequencies. Some of this is due to lack of a uniform complication classification system between studies.[14] This current study chose to utilize the commonly used and accepted system of the modified-Clavien-Dindo classification system and then grouped complications further into the Memorial Sloan-Kettering Cancer Center (MSKCC) subcategorization system.

Modified Clavien-Dindo System

Post-operative complications were first be graded and classified according to the modified Clavien-Dindo system (See Appendix Table B).[15] Grade I included any complication not requiring intervention, except antiemetics, antipyretics, analgesics, diuretics, electrolytes, bedside wound care, and physical therapy. Grade II included complications requiring blood transfusions, total parenteral nutrition, or pharmacologic therapy beyond those listed under Grade I. Grade III included surgical, endoscopic or radiological intervention. Grade IV was any life-threatening complication requiring Intensive Care Unit management.

Grade V was any death.[15] Grades I-II were considered minor complications, and Grades III–V were considered major complications.[16]

MSKCC System

After applying the modified Clavien-Dindo system to complication grading, the MSKCC system was used to group complications (See Appendix Table C).[17] The MSKCC system uses 11 subcategories. These subcategories of complications aim to further describe the nature of complications. Subcategories include: gastrointestinal, infectious, wound, genitourinary, cardiac, pulmonary, bleeding, thromboembolic, neurological, miscellaneous, and surgical.[17]

Cost-to-patient

Cost-to-patient was defined as the dollar amounts charged consistently for services rendered. Cost-to-patient charges were grouped into four service categories (Operative, Diagnostic, Hospital, Other) and then into various subcategories.

Cost-to-patient charges were the most reliable and consistent cost information available from our institutional billing department from time of surgery until 30-days post-operatively. Direct costs were unavailable. This does not include the amount reimbursed, pre-negotiated charges, or insurance negotiated charges as these would be biased by insurance variance, nor is it the direct cost. Inflation occurred uniformly at 3% per year from 2009 to June 2012, while 5% inflation occurred from July 2012 to 2015. It was not deemed necessary to adjust for this (see *Discussion*). Amortized and maintenance robot costs were not directly included within the robotic operative charges for three reasons: (1) these data were unavailable (2) these costs are contracted and paid for by the entire hospital and dispersed amongst all departments that utilize it, not just Urology, and (3) this study provides a direct charge-to-charge, service-to-service comparison of robotic and open approaches during the 30-day perioperative period not influenced by changing purchase and maintenance contracts.

Statistical Analysis

Categorical variables are reported using absolute and relative frequencies. Differences in categorical variables were determined using chi-square testing. Continuous variables approximately normally distributed are reported using mean and standard deviation. Two-sample t-tests are used to compare those variables. Continuous variables not normally distributed are reported using median and interquartile range (IQR), with differences compared using Wilcoxon Rank Sum test.

Univariate and multivariable logistic regression were used to determine predictive variables for both 30-day complication and readmission, separately. Univariate and multivariable linear regression were used to determine significant predictive variables for 30-day cost-to-patient charges.

Model diagnosis was performed using leverage testing, Cook's Distance, DFBETA and DFFITS methods. Stata software was utilized for all analyses (StataCorp, v13.1, College Station, TX).[18]

The variable age was categorized into five precise levels (<50, 50-59, 60-69, 70-79, ≥80 years) to minimize potential residual confounding as opposed due to only dichotomizing the continuous covariate.[19]

Power Analysis

Using a baseline estimate of 40% of patients with at least one complication in the open group, our study is approximately 90% powered to detect a clinically meaningful difference in complication frequency of approximately 20 percentage points using a two-sided chi-squared level of significance of 0.05.

Using a baseline estimate of 30% of patients with at least one readmission in the open group, our study is only approximately 40% powered to detect a clinically meaningful difference in readmission frequency of 10 percentage points using a two-sided chi-squared level of significance of 0.05.

RESULTS

One hundred forty-nine patients received ORC and 100 patients received RARC. Tables 1a-b display the patient, clinical, and surgical characteristics of study patients. Patient, clinical and surgical characteristics were similar between open and robotic groups, respectively, except for the following clinically meaning differences: median estimated blood loss (EBL) (600cc versus 150cc, $p<0.01$), operative time (6.19 versus 6.85, $p<0.01$), and median length of stay (LOS) (7 days versus 5 days, $p=0.01$). Mortality for the robotic group was 1% (1 of 100) compared to 2% (3 of 149) for the open group ($p=0.65$).

Complication

Crude Complication Estimates

The frequencies of recorded complications are presented in Tables 2a-c. The frequency of patients with at least one 30-day complication was 86% for open compared to 66% for robot ($p<0.01$). Significantly more patients had at least one grade 2-5 complication in the open group (69%) compared to robotic group (42%) ($p<0.01$). Significantly more patients in the open group (85%) experienced at least one 30-day minor complication compared to robot (66%) ($p<0.01$). Minor gastrointestinal and bleeding complications were significantly increased in the open group compared to robot (50 vs 41%, $p=0.01$; 52 vs 11%, $p<0.01$, respectively). Fifty percent of open patients required blood transfusion compared to only 11% in the robot group ($p<0.01$).

Patients in the open group had significantly more (19%) major complications compared to the robotic group (10%) ($p=0.04$). No significant differences in frequency of individual major complication MSKCC categories existed between groups.

Univariate Analysis: Complication

The robotic approach was significantly associated with decreased odds of having a complication within 30 days post-operatively (p<0.04) (Table 3a). Other significant associations on univariate analysis include clinical stage (p=0.01) (cT1, cT2, cT3, cT4; OR 5.15, 10.72, 14.78, 31.67; p=0.01, <0.01, 0.1, 0.03, respectively), preoperative creatinine (OR 2.89, p=0.02), estimated blood loss (OR 1.0, p<0.01), operating time (OR 1.17, p=0.02), and length of stay (OR 1.61, p<0.01).

Adjusted Complication Estimates

Multivariable Analysis: Complication

Variables considered for potential inclusion into the multivariable regression model included: surgical approach, prior chemotherapy, clinical stage, diversion type, pathological T stage, Charlson Comorbidity Score, preoperative creatinine, preoperative hematocrit, operating time, and length of stay.

In the final multivariable model, robotic approach was a significant predictor for at least one complication within 30 days post-surgery (OR 0.44, p=0.049) (Table 3b). Other significant variables in the final multivariable model include clinical stage T2 (OR 5.66, p=0.02) (overall clinical stage, p=0.11), and length of stay (OR 1.41, p=0.01). No clinically meaningful effect modifiers were identified. No specific confounders were explored given that during multivariable model building, potential confounders were already included in the model.

Readmission

Crude Readmission Estimates

There was no significant difference in the number of patients readmitted at least one time within 30 days following cystectomy in the open group (31%) compared to robotic group (27%) (p=0.51).

Univariate Analysis: Readmission

Surgical approach was not significantly associated with having at least one admission within 30 days following cystectomy (OR 0.83, p=0.51) (Table 4a). Important covariates on univariate analysis include diversion type (neobladder, OR 3.31, p<0.01), preoperative BMI (OR 1.07, p=0.01), estimated blood loss (OR 1.0, p=0.04), and operating time (OR 1.34, p<0.01).

Adjusted Readmission Estimates

Multivariable Analysis: Readmission

Variables considered for potential inclusion into the multivariable regression model included: surgical approach, smoking history, race, prior abdominal surgery, prior pelvic radiation, diversion type, pathological T stage, preoperative BMI, operating time, and length of stay. Pathological T stage was removed from the model early on as it was not deemed an important variable by likelihood ratio test when comparing the model with and without it included (p=0.09).

In the final multivariable model, robotic approach was not a significant predictor for at least one readmission within 30 days following cystectomy (OR 0.70, p=0.29) (Table 4b). Significant covariates predictive of readmission include urinary diversion type (p<0.01) (neobladder, OR 4.05, p<0.01), Charlson Comorbidity Score (OR 1.22, p=0.02), preoperative BMI (OR 1.07, p=0.02), operating time (OR 1.37, p=0.01), and length of stay (OR=0.87, p=0.01). No clinically meaningful effect modifiers were identified. No specific confounders were explored given that during multivariable model building, potential confounders were already included in the model.

Cost-to-Patient

Crude Cost-to-patient Estimates

Median 30-day total cost-to-patient was significantly reduced in the robotic group versus open ($57,336 versus $69,976, p<0.01) (Table 5). The Operative service category was not significantly different between surgical approaches (p=0.10), while the remaining three service categories (Diagnostic, Hospital and Other) were significantly less in the robotic group compared to open (all p<0.01). There was more Diagnostic service charges in the open group compared to the robotic group, so when excluding this service category from comparison, the overall median cost-to-patient remained significantly reduced for the robotic group compared to the open group ($52,368 versus $59,479, p<0.01). Specifically, the open group had significantly more patients who had any imaging within 30 days post-surgery (85%) compared to the robotic group (62%) (p<0.01). Within the Hospital service category, Room & Board, Inpatient Medications, and Pharmacy subcategories all significantly contributed to increased cost-to-patient in the open group (all p<0.01).

In Table 6, the frequencies and median total cost-to-patient are displayed for each surgical approach group. The frequencies of open cystectomy are a bit higher in the later years, whereas the robotic group is more frequent in the later years. The median total cost-to-patient was consistently and significantly reduced in four out of the seven years (2010-2013). This finding was significant for years 2010-2013. Only in 2015 did the open approach demonstrate a reduced total median cost-to-patient compared to the robotic group (p=0.07). Using a regression analysis and likelihood ratio test with surgical group and year of surgery included, year of surgery did not significantly affect the total cost-to-patient (p=0.73).

Univariate Analysis: Cost-to-Patient

Robotic approach was a significantly associated with a reduced total median cost-to-patient compared to open approach in the univariate analysis (p<0.01) (Tables 7a). Other significant covariates associated with reducing total median cost-to-patient include: only pT2 stage compared to pT0/Ta/Tis (p=0.04), having an extended lymph node dissection (p<0. 01) and general anesthesia compared to general plus an epidural) (p<0.01). Significant covariates suggesting increased cost-to-patient include: being from a rural region compared to urban (p=0.03), having a perioperative blood transfusion (p<0.01), having clinical stage of cT1-T4 compared to cTa/Tcis (p=0.01), neobladder diversion compared to ileal conduit (p=0.01), higher Charlson Comorbidity Score (p=0.03), higher preoperative BMI (p<0.01), only pT4 stage compared to pT0/Ta/Tis (p=0.07), higher preoperative creatinine (p<0.01), higher estimated blood loss (p<0.01), longer operating time (p<0.01), and longer length of stay (p<0.01).

Adjusted Cost-to-patient Estimates

Multivariable Analysis: Cost-to-Patient

in multivariable analysis, robotic approach was associated with approximately an 18% reduction in total median cost-to-patient within 30 days post-cystectomy compared to the open approach (p<0.01) (Table 7b). Age greater than 50 years old was predictive of a reduced total cost-to-patient (p=0.03). Pathological tumor stage (p<0.01) (pT4, p=0.02), Charlson Comorbidity Score (p<0.01) preoperative BMI (p=0.03), operating time (p<0.01), and length of stay (p=0.01) were all predictive of increased total cost-to-patient. Other non-predictive covariates included in the model were prior chemotherapy, clinical stage, and urinary diversion type. No clinically meaningful effect modifiers were identified. No specific confounders were explored given that during multivariable model building, potential confounders were already included in the model.

DISCUSSION

In our analysis, robotic cystectomy demonstrates reduced gastrointestinal and bleeding complications, similar readmission frequency, and reduced total cost-to-patient when assessing the 30-day post-cystectomy perioperative period relative to open cystectomy. Couple this with prior studies suggesting fewer complications and lower blood loss, robotic cystectomy is a strong alternative to the standard open cystectomy when performed in the appropriate high-volume setting where institutional costs of the robot acquisition and maintenance are dispersed throughout the institution.

Bladder Cancer is a Costly Cancer to Manage with High Complication and Readmission Frequency

Bladder cancer is a common malignancy in the U.S. that is one of the most costly cancers to manage.[5] Additionally, it has high post-operative morbidity ranging from 11 to 68% and readmission frequency up to 40%.[5-7, 20-22] Currently, other studies suggest RARC may offer *operative* cost disadvantages compared to ORC due to the robot's high amortization, maintenance, supply, and longer operating time.[23-29] This is of course only considering the time period when amortization is actively being paid. In contrast, some recent studies suggest the robot could have *post-operative* cost advantages over ORC due to fewer complications,[10] lower blood loss,[23, 29, 30] lower transfusion rates,[27] earlier return to bowel function,[31] and shorter post-operative hospital lengths of stay.[10, 26, 29, 30, 32] Importantly, similar oncologic outcomes comparing RARC and ORC have been shown.[23, 31, 33, 34] A recent systematic review suggested that RARC may provide overall cost reduction compared to ORC when reduced RARC post-operative complications were factored in,[35] but more data are needed to assess this clouded relationship.[4, 10, 35] As such, our findings are consistent with other reports, and our study adds a unique perspective by excluding the amortization (only 5 years to pay-off) and maintenance costs of the robot since they are, in our institution, hospital-wide costs and dispersed amongst all departments, and therefore would not be valid to include in the cost-to-patient comparison.

Complications following Open and Robotic Cystectomy Are Common

ORC Complication Estimates

Studies documenting post-operative complications demonstrate the high morbidity of this procedure. This may be largely due to the older patient population with bladder cancer and multiple comorbidities, such as smoking and diabetes.[14] While large variability exists in complication estimates due to non-uniform complication classifications used, an estimate of minor complications for patients undergoing open radical cystectomy was reported to be approximately 30% by Chang et al.[36-39] The risk for a major complication with this procedure is about 5%, defined as a myocardial infarction, cerebrovascular event, pulmonary embolus, sepsis, respiratory failure, return to the operative room, or death. The mortality rate was reported to be approximately 1% to 3%.[36-39] These findings likely underreport the true complication frequency due to the grading system used, whereas our study used the modified Clavien-Dindo and MSKCC systems that capture more events that are based upon what was done to address the complication.

Studies report that some of the most common minor complications include anemia (~45%, pre- versus post-operative hematocrit)[39] and ileus (~18-23%, lack of bowel movement beyond four days post-operatively).[36, 37] Approximately 30% of patients require blood transfusions.[36, 39] Chang et al. demonstrated that increased peri-operative blood loss and transfusion requirement correlate with delayed discharge and thus higher room and board cost.[36] These are consistent with our data, and it suggests strongly that the reduced complications with RARC seem to strongly influence a reduced cost-to-patient and minimize the number of interventions in response to a complication.

RARC Complications Estimates

A study by Johar et al. specifically assessed complications after RARC and reported that 41% of patients experienced a complication within 30-days of surgery.[40] Over 80% of these patients only had low grade complications (grade ≤2 using the modified Clavien-Dindo and MSKCC classification).[40] Most common complications were gastrointestinal and 30-day mortality was 1.3%.[40] While variability does still exist among estimates from various studies, notice that these complication estimates are overall higher compared to earlier ORC estimates. This is largely attributed to the difference in classification systems used for either surgical approach and in the Chang et al. studies from the early 2000s.[14, 17] Newer post-operative complication classification systems (modified from earlier versions) provide more accurate collection and therefore report higher numbers.[17, 41] Our overall 30-day complication estimate was 66% of patients in the robotic group compared to 86% in the open group, higher than other reports, and reflecting our use of the modified Clavien-Dindo and MSKCC systems.

Risk Factors Have Been Difficult to Identify for Complications and Readmissions

Risk Factors for Complications

Chang et al. found that only requiring a blood transfusion was a risk factor for other minor complications (p=0.03), whereas being an ethnic minority, having a major complication, or an EBL of greater than 600 ml were not predictors.[37] In the current study, blood transfusion was a grade 2 complication, and EBL was directly correlated with the surgical approach. Therefore, neither was included in the multivariable model, thus allowing surgical approach to remain a significant predictor, with robotic cystectomy associated with significantly lower odds of complication within 30-days post-operatively. Furthermore, length of stay was a significant predictor of having at least 1 complication within 30-days post-operatively, which favors an approach that can reduce the length of time in the hospital.

Risk Factors for Readmission

Reported readmission rates are consistent between our study (approximately 30% for both groups) and prior studies. Despite readmissions after cystectomy being common, risk factors have been challenging to identify.[5-7, 16, 20, 22] Compared to other urologic procedures with multiple risk factors identified, few studies exist identifying risk factors after cystectomy.[6, 16] One study found only age to be a risk factor for readmission.[42] Another study reported that being African American, receiving an orthotopic neobladder, being discharged to a post-acute care facility, and patients with two or more comorbidities appear to be more likely to be readmitted within 30-days following cystectomy.[6] Our study confirms that receiving an orthotopic neobladder, having a higher comorbidity score, and non-Caucasian race increases the odds of readmission. In addition, we found that higher preoperative BMI and operative time, and shorter length of stay to be significant predictors of readmission. Strategies to identify and target these and other identifiable risk factors for readmission following cystectomy are essential to optimize patient safety.

An interesting question persists, if a shorter length of stay is suggestive of reduced cost and fewer complications, but a longer stay is suggestive of fewer readmissions, which should be favored? The answer is likely a delicate balance by the surgeon of sensing each patient's proximity to either go home or spend a few more days in-house, *just in case*.

Cost and Cost-to-patient

While crude dollar comparison between studies and institutions is futile, the relative comparisons of open versus robotic costs (or costs-to-patients) are still valid and useful. Smith et al. compared fixed and variable costs of open versus robotic cystectomy while taking into account amortization of the robot during the perioperative period. Authors reported that the robotic approach cost $1640 higher more than open (robot $16,248 vs open $14,608).[29] This, however, does not take into account what the cost comparison would be after the period of amortization is complete, as our study simulates. Additionally, the methods do not explicitly state that hospital costs after surgery other than transfusion and length of stay were taken into account. Without doing so, a large portion of cost may have been unaccounted for during the perioperative period in the Smith study. Additionally, in a systematic review by Lee et al. robotic cystectomy was shown to be less expensive than open cystectomy when complications were taken into account.[35] This is similar to our study, too, where a large contributor of the cost increase for open cystectomy compared to robotic cystectomy appeared to be the length of stay. Leow et al reported that robotic cystectomy added approximately $4236 per case largely due to supply cost, but this cost difference disappeared in high-volume centers (≥ 19 cases per year) or for high-volume surgeons (≥ 7 cases per year), which satisfies the current study's criteria.[32] Our analysis is unique and adds information where other studies have fallen short because it captures the breadth of all 30-day perioperative service charges excluding amortization costs allowing a more accurate direct charge-to-charge comparison of the two surgical approaches.

Predictors of Cost-to-Patient

We found robotic cystectomy to be predictive of a reduced median total cost-to-patient compared to open approach. Despite similar Operative service charges, Diagnostic, Hospital and Other service charges after cystectomy were significantly less expensive for robotic cystectomy, which likely contributed to this finding. Furthermore, pathological T stage, as a whole, was significantly associated with cost-to-patient, whereas pT4 was specifically predictive of an increase in cost-to-patient compared to Ta/Tcis/T0, which intuitively makes sense. Furthermore, higher preoperative comorbidity, preoperative BMI, operating time and shortened length of stay all predict reduced median total cost-to-patient. This is what would be expected. Interestingly, though, age category was inversely related to cost-to-patient. As age increased above 50 years old, the cost-to-patient decreased slightly, but significantly. The reason for this may be that the youngest patients with bladder cancer requiring cystectomy may intrinsically have more health service requirements given either genetically worse disease or long-term health needs that we were unable to detect with Charlson Comorbidity Score. Only age ≥ 80 years old had significantly higher CCS in the open group compared to robot (p=0.02), but was adjusted for in the multivariable model.

Limitations and Considerations

Missing values and complete statistical separation for some variables

Missing data values (pre-operative creatinine) reduced the analyzable sample size from 249 in some multivariable regression analyses. Additionally, complete statistical separation existed for diversion type and pathological T stage for the complication and readmission logistic regression analyses, in addition to clinical stage for the readmission logistic regression. This required use of a penalized maximum likelihood ratio, Firth Logit. Essentially, for any single categorical level, only one of the two possible outcomes existed, thus making it predict the outcome perfectly. While this is a good problem to have, this situation forced our estimations to be more conservative.

Direct-cost versus Cost-to-patient Charge Data

Direct cost data would have been preferred, but was not available. While cost-to-patient charge data does not allow direct inter-institutional comparisons, it still does allow valid intra-institutional analysis between the two surgical approaches. Furthermore, the relevant comparison is less the absolute amount, but rather the relative comparison between the two groups for both inter- or intra-institutional comparisons. Therefore, cost-to-patient charge data is an appropriate relative surrogate of cost comparisons.

Furthermore, the selected method of cost-to-patient comparison might be wrongly assumed to be inferior to other monetary comparison methods. We chose to perform a cost comparison instead of a cost-benefit analysis (CBA) because of our question and data. Given that our data inherently contain the probabilities and proportions of characteristics attributable to cost, there is no need to speculate and generate Quality Adjusted Life Years (QALYs) in terms of cost that would be used in a CBA or cost-effectiveness analysis (CEA), which would additionally require speculated probabilities. In assuming our outcomes are fairly similar for our two patient groups, the comparison in effect becomes a CBA.

Surgeon Differences

Differences in surgeon techniques and habits could affect all three outcomes. However, given our sample size, it is unlikely that difference would have been detected. Therefore, surgeon covariates were not felt necessary to control.

Selection Bias

Concern for death within 30 days post-operatively in one group significantly more than another group would, of course, bias the likelihood of readmission. Fortunately, only three patients from the open group and one from the robotic group died during the 30-day post-operative period. Therefore, this bias is not of concern.

Duration of Observation

Thirty days post-operative was chosen as the duration of observation because events and cost-to-patient charges within this time window are more likely to be directly associated with the surgical intervention rather than other remote unrelated events beyond 30 days post-operatively.

Secular Bias

Table 6 shows that for only 2010 and 2014 there were significantly different proportions of surgeries performed for each group. One concern is for secular bias, whereas differences in protocols and processes between years may have existed leading to undetected effects on complications, readmissions, or cost-to-patient. However, the remaining years demonstrate no significant differences in the proportion of surgeries performed for each group. Therefore, the overall analysis is unlikely to be severely affected by this.

Detection Bias

Patients readmitted at outside hospitals may not be captured in the OHSU medical record system. However, given that the study looked at only 30-days post-operatively, most outside hospitals contacted OHSU as the readmission was most likely due to their recent surgery at OHSU. Thus, a telephone encounter was often documented in the OHSU medical record when patients were readmitted to outside hospitals within 30-days post-operatively. Even if this were a concern, the bias would be nondifferential.

Additionally, cost of readmissions at outside hospitals within 30-days post-operatively were not captured in the cost-to-patient totals collected from OHSU Billing for this study. To address this, a separate exploration into source data would be needed. For example, patients from each surgical group who were readmitted to OHSU versus an outside hospital would need to be tallied. If no significant difference in the number of outside readmissions between groups exists, then this bias is of lesser concern.

Inflation

Inflation was not accounted for because the 5 out of 7 years in Table 6, the proportions of surgeries by group and year were not significantly different. Therefore, it is unlikely that small amount of inflation would affect the large observed median difference in total cost-to-patient.

Lack of Propensity Score Matching

Propensity scoring was suggested to handle the concern for a patient's propensity to choose one surgical approach over another or to deal with differences in patient characteristics between groups. However, Table 1 demonstrates strong similarity between surgical groups and the indications were exactly the same for whether a patient chose the open or robotic approach. This holds true for the frequency distribution of urinary diversion types which were not significantly different between groups. Thus, propensity score matching was not deemed necessary.

Potential Collinearity

In using the Charlson Comorbidity Score, which includes age as an adjuvant component to the Charlson Comorbidity Index, concern for collinearity with the simultaneous usage of the categorical age variable arose, but the variance inflation factor reassured that no significant collinearity existed.

Underpowered for Readmission

We lacked sufficient statistical power to detect a clinically meaningful difference of 10 percentage points in readmission frequency between surgical approach groups. This limitation was known at the outset of this study.

CONCLUSION

Despite these potential limitations, we have shown that robotic cystectomy can be a strong alternative to the current standard of care, open cystectomy, with reduced 30-day complication frequency, blood loss, need for transfusion, and length of hospital stay. Robotic cystectomy was predictive of reduced 30-day complication. In contrast, neither surgical approach was significantly associated with or predictive of 30-day post-operative readmission.

Without taking into account upfront robotic purchase price and maintenance costs, our data demonstrate a direct charge-for-charge comparison of surgical approach suggesting that robotic cystectomy demonstrates a reduced cost-to-patient during the 30-day perioperative period. As robotic amortization reaches maturity and maintenance contracts decrease with greater availability of robotic technology, robotic cystectomy may demonstrate a true overall cost-to-patient reduction compared to open cystectomy, particularly in a high-volume surgical center and taking into account 30-day post-operative cost-to-patient charges.

Future Directions

Future studies may build upon these results by focusing on further strategies to identify and modify risk factors for complication and readmission following cystectomy. Beyond clinical databases, financial databases within institutions should be called upon to make financial processes and direct cost information transparent in order for health systems, not just individual institutions, to make the most accurate and comparable information for the betterment of our patient care and health system.

Identifying the most cost-conscious surgical approach for thousands of patients could translate into substantial cost savings over time. For the health system, reduced spending on complications or readmissions related to a particular operative method would have far reaching financial impact and enhancement of patient experience to minimize burdensome and costly hospital readmissions and complications related to their cancer treatment.

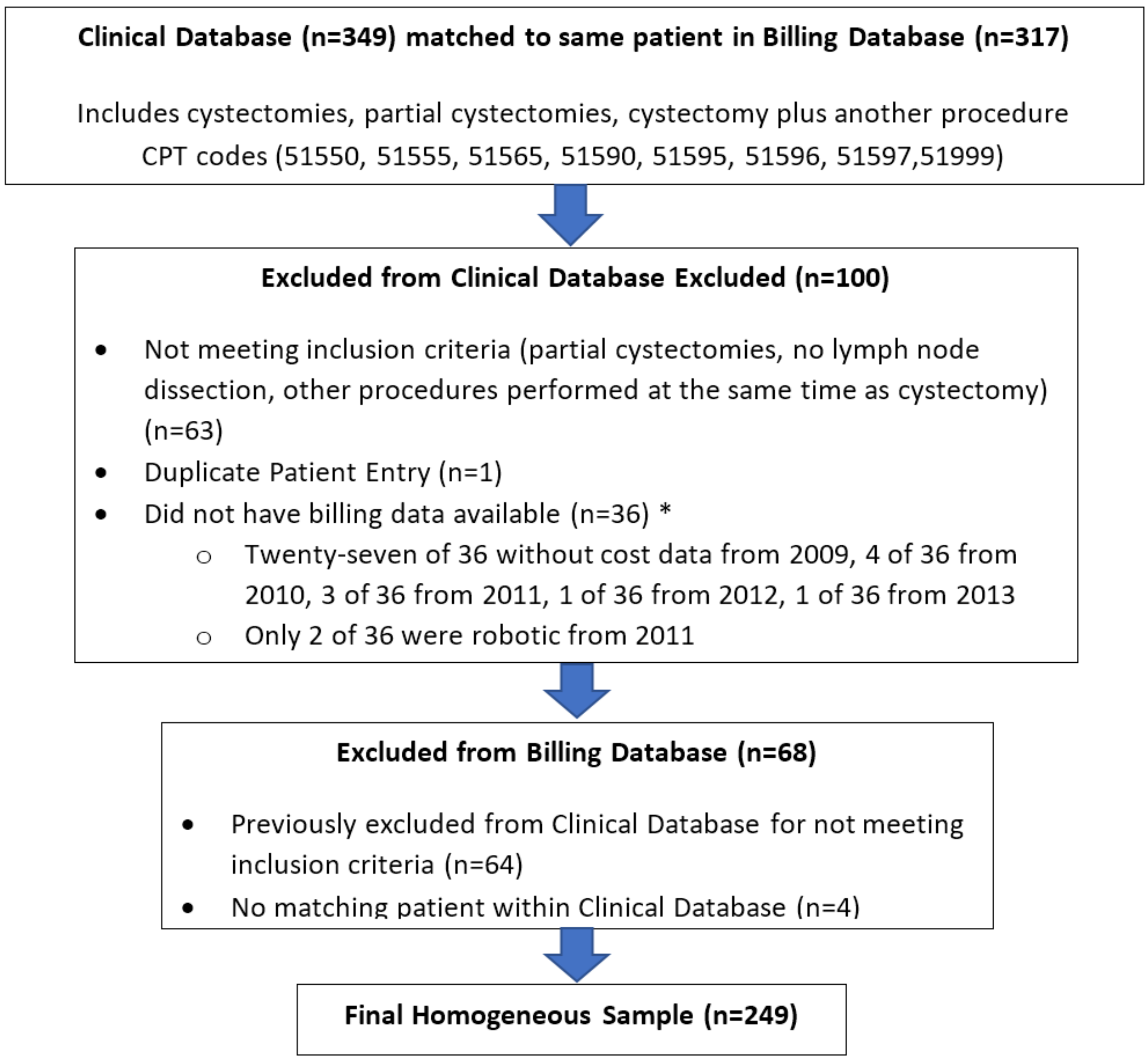
REFERENCES

1. Luchey, A. M., Agarwal, G., Poch, M. A.: Robotic-Assisted Radical Cystectomy. Cancer Control, **22:** 301, 2015
2. Ferlay, J., Soerjomataram, I., Dikshit, R. et al.: Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012. Int J Cancer, **136:** E359, 2015
3. Siegel, R. L., Miller, K. D., Jemal, A.: Cancer statistics, 2015. CA Cancer J Clin, **65:** 5, 2015
4. Johnson, D. C., Greene, P. S., Nielsen, M. E.: Surgical advances in bladder cancer: at what cost? Urol Clin North Am, **42:** 235, 2015
5. Tandogdu, Z., Vale, L., Fraser, C. et al.: A Systematic Review of Economic Evaluations of the Use of Robotic Assisted Laparoscopy in Surgery Compared with Open or Laparoscopic Surgery. Appl Health Econ Health Policy, **13:** 457, 2015
6. Minnillo, B. J., Maurice, M. J., Schiltz, N. et al.: Few modifiable factors predict readmission following radical cystectomy. Can Urol Assoc J, **9:** E439, 2015
7. Mmeje, C. O., Martin, A. D., Nunez-Nateras, R. et al.: Cost analysis of open radical cystectomy versus robot-assisted radical cystectomy. Curr Urol Rep, **14:** 26, 2013
8. Zehnder, P., Gill, I. S.: Cost-effectiveness of open versus laparoscopic versus robotic-assisted laparoscopic cystectomy and urinary diversion. Curr Opin Urol, **21:** 415, 2011
9. Dalela, D., Ahlawat, R., Sood, A. et al.: WITHDRAWN: The growth of computer-assisted (robotic) surgery in urology 2000–2014: The role of Asian surgeons. Asian Journal of Urology, **2:** 1, 2014
10. Lee, R., Ng, C. K., Shariat, S. F. et al.: The economics of robotic cystectomy: cost comparison of open versus robotic cystectomy. BJU Int, **108:** 1886, 2011
11. Takenaka, A.: Current Status of Robot-Assisted Radical Cystectomy: What is the Real Benefit? Yonago Acta Med, **58:** 95, 2015
12. Health, O. O. o. R.: Oregon zip codes and their ORH urban/rural designation, vol. 2016, p. Oregon zip codes and their ORH urban/rural designation, 2015
13. Charlson, M., Szatrowski, T. P., Peterson, J. et al.: Validation of a combined comorbidity index. J Clin Epidemiol, **47:** 1245, 1994
14. Cha, E. K., Wiklund, N. P., Scherr, D. S.: Recent advances in robot-assisted radical cystectomy. Curr Opin Urol, **21:** 65, 2011
15. Dindo, D., Demartines, N., Clavien, P. A.: Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg, **240:** 205, 2004
16. Harraz, A. M., Osman, Y., El-Halwagy, S. et al.: Risk factors of hospital readmission after radical cystectomy and urinary diversion: analysis of a large contemporary series. BJU Int, **115:** 94, 2015
17. Shabsigh, A., Korets, R., Vora, K. C. et al.: Defining early morbidity of radical cystectomy for patients with bladder cancer using a standardized reporting methodology. Eur Urol, **55:** 164, 2009
18. StataCorp: Statistical Software: Release 13, 13.1 ed. College Station, TX: StataCorp LP, 2013
19. Groenwold, R. H., Klungel, O. H., Altman, D. G. et al.: Adjustment for continuous confounders: an example of how to prevent residual confounding. CMAJ, **185:** 401, 2013
20. Kulkarni, J. N.: Perioperative morbidity of radical cystectomy: A review. Indian J Urol, **27:** 226, 2011
21. Muto, G., Collura, D., Simone, G. et al.: Stapled orthotopic ileal neobladder after radical cystectomy for bladder cancer: Functional results and complications over a 20-year period. Eur J Surg Oncol, **42:** 412, 2016
22. Wittig, K., Ruel, N., Barlog, J. et al.: Critical Analysis of Hospital Readmission and Cost Burden After Robot-Assisted Radical Cystectomy. J Endourol, **30:** 83, 2016
23. Bochner, B. H., Dalbagni, G., Sjoberg, D. D. et al.: Comparing Open Radical Cystectomy and Robot-assisted Laparoscopic Radical Cystectomy: A Randomized Clinical Trial. Eur Urol, **67:** 1042, 2015

24. Desai, M. M., Gill, I. S., de Castro Abreu, A. L. et al.: Robotic intracorporeal orthotopic neobladder during radical cystectomy in 132 patients. J Urol, **192:** 1734, 2014
25. Giannarini, G., Palumbo, V., Ficarra, V.: Words of Wisdom. Re: robotic intracorporeal orthotopic neobladder during radical cystectomy in 132 patients. Eur Urol, **67:** 1191, 2015
26. Martin, A. D., Nunez, R. N., Castle, E. P.: Robot-assisted radical cystectomy versus open radical cystectomy: a complete cost analysis. Urology, **77:** 621, 2011
27. Novara, G., Catto, J. W., Wilson, T. et al.: Systematic review and cumulative analysis of perioperative outcomes and complications after robot-assisted radical cystectomy. Eur Urol, **67:** 376, 2015
28. Winters, B. R., Bremjit, P. J., Gore, J. L. et al.: Preliminary Comparative Effectiveness of Robotic Versus Open Radical Cystectomy in Elderly Patients. J Endourol, **30:** 212, 2016
29. Smith, A., Kurpad, R., Lal, A. et al.: Cost analysis of robotic versus open radical cystectomy for bladder cancer. J Urol, **183:** 505, 2010
30. Ahmed, K., Ibrahim, A., Wang, T. T. et al.: Assessing the cost effectiveness of robotics in urological surgery - a systematic review. BJU Int, **110:** 1544, 2012
31. Nix, J., Smith, A., Kurpad, R. et al.: Prospective randomized controlled trial of robotic versus open radical cystectomy for bladder cancer: perioperative and pathologic results. Eur Urol, **57:** 196, 2010
32. Leow, J. J., Reese, S. W., Jiang, W. et al.: Propensity-matched comparison of morbidity and costs of open and robot-assisted radical cystectomies: a contemporary population-based analysis in the United States. Eur Urol, **66:** 569, 2014
33. Raza, S. J., Wilson, T., Peabody, J. O. et al.: Long-term oncologic outcomes following robot-assisted radical cystectomy: results from the International Robotic Cystectomy Consortium. Eur Urol, **68:** 721, 2015
34. Froehner, M., Koch, R., Wirth, M. P.: Re: Syed Johar Raza, Timothy Wilson, James O. Peabody, et al. Long-term Oncologic Outcomes Following Robot-assisted Radical Cystectomy: Results from the International Robotic Cystectomy Consortium. Eur Urol 2015;68:721-8. Eur Urol, **68:** e109, 2015
35. Lee, R., Chughtai, B., Herman, M. et al.: Cost-analysis comparison of robot-assisted laparoscopic radical cystectomy (RC) vs open RC. BJU Int, **108:** 976, 2011
36. Chang, S. S., Baumgartner, R. G., Wells, N. et al.: Causes of increased hospital stay after radical cystectomy in a clinical pathway setting. J Urol, **167:** 208, 2002
37. Chang, S. S., Cookson, M. S., Baumgartner, R. G. et al.: Analysis of early complications after radical cystectomy: results of a collaborative care pathway. J Urol, **167:** 2012, 2002
38. Chang, S. S., Cookson, M. S., Hassan, J. M. et al.: Routine Postoperative Intensive Care Monitoring Is Not Necessary after Radical Cystectomy. The Journal of Urology, **167:** 1321, 2002
39. Chang, S. S., Smith, J. A., Jr., Wells, N. et al.: Estimated blood loss and transfusion requirements of radical cystectomy. J Urol, **166:** 2151, 2001
40. Johar, R. S., Hayn, M. H., Stegemann, A. P. et al.: Complications after robot-assisted radical cystectomy: results from the International Robotic Cystectomy Consortium. Eur Urol, **64:** 52, 2013
41. Colombo, R.: Editorial comment on: Defining early morbidity of radical cystectomy for patients with bladder cancer using a standardized reporting methodology. Eur Urol, **55:** 175, 2009
42. Leow, J. J., Gandaglia, G., Sood, A. et al.: Readmissions after major urologic cancer surgery. Can J Urol, **21:** 7537, 2014

FIGURES AND TABLES

Figure 1: Eligibility and enrollment from based upon a combination of a clinical and a billing database containing all cystectomies from 2009 to 2015 at Oregon Health & Science University



* Exclusion of 36 patients from the Clinical Database due to no matching patient in the Cost-to-patient Database is appropriate as the majority of these are from 2009 only. This missing ability to capture the majority of these patients from 2009 is likely due to a billing/system issue present in 2009 alone. Given that this is uniform across one year only, concern for bias here is minimized. Furthermore, this makes the entire sample size more homogeneous as open cystectomies in 2009 routinely sent patients to the ICU post-operatively. After 2009, this was no longer standard practice for either open or robotic cystectomies.

TABLE 1. Patient, Clinical and Surgical Characteristics of Patients Undergoing either Open or Robotic Cystectomy

Table 1a. Patient and clinical characteristics of patients undergoing either open or robotic cystectomy

	Cystectomy Approach		
Patient Characteristics	Open n=149	Robot n=100	p-Value
Age in years, No. (%)[1]			0.24
< 50[2]	5 (3%)	5 (5%)	0.53
50-59[2]	21 (14)	12 (12)	0.63
60-69[2]	55 (36)	34 (12)	0.64
70-79[2]	55 (36)	31 (31)	0.34
≥ 80[2]	13 (9)	18 (18)	0.03*
Female, No. (%)[2]	42 (28)	16 (16)	0.03*
Caucasian, No. (%)[2]	144 (97)	100 (100)	0.06
Smoking history, No. (%)[2]	113 (76)	79 (79)	0.56
Living location, No. (%)[2]			0.71
Urban	65 (44)	46 (46)	-
Rural	84 (56)	54 (54)	-
Clinical Characteristics			
Mean Charlson Comorbidity Score (±SD)[3]	3.9 (±1.9)	3.7 (±2)	0.62
Mean preoperative BMI, kg/m^2 (±SD)[3]	28.2 (±5.7)	27.8 (±5.2)	0.58
Prior pelvic radiation, No. (%)[2]	12 (8)	13 (13)	0.20
Neoadjuvant chemotherapy, No. (%)[2]	38 (26)	23 (23)	0.65
Prior abdominal surgery, No. (%)[2]	75 (50)	52 (52)	0.80
Clinical Stage, No. (%)[1]			0.29
cT0/Ta/Tcis[2]	5 (3)	8 (8)	0.11
cT1[2]	36 (24)	30 (30)	0.31
cT2[2]	98 (66)	56 (56)	0.12
cT3[4]	2 (1)	1 (1)	1.00
cT4[4]	3 (2)	4 (4)	0.44
Unavailable	5 (3)	1 (1)	0.41
Value of preoperative labs (±SD)[3]			
Mean Creatinine, mg/dL	1.1 (±0.46)	1.12 (±0.43)	0.75
Mean Hematocrit, %	38.29 (±6.3)	38.7 (±4.8)	0.61

IQR=interquartile range
[1] ANOVA
[2] Chi-square
[3] T-test
[4] Fisher's exact
[5] Wilcoxon rank sum

Table 1b. Surgical characteristics of patients undergoing either open or robotic cystectomy

	Cystectomy Approach		
Surgical Characteristics	Open n=149	Robot n=100	p-Value
Median Estimated Blood Loss, cc (IQR)[5]	600 (350-1200)	150 (100-250)	<0.01*
Mean Operating time, hours (SD)[3]	6.19 (±1.7)	6.85 (±1.16)	<0.01*
Median Length of Stay, days (IQR)[5]	7 (5-8)	5 (4-8)	<0.01*
Diversion Type No. (%)[1]			0.12
Ileal Conduit[2]	110 (74)	84 (84)	0.06
Neobladder[2]	37 (25)	16 (16)	0.10
Continent Cutaneous Diversion[2]	2 (1)	0 (0)	0.25
Pathological Tumor Stage, No. (%)[1]			0.46
pT0/Ta/Tis[2]	45 (30)	28 (28)	1.00
pT1[2]	11 (7)	9 (9)	0.65
pT2[2]	17 (11)	15 (15)	0.41
pT3[2]	62 (42)	33 (33)	0.17
pT4[2]	14 (9)	15 (15)	0.02*
Pathological Nodal Stage, No. (%)[1]			0.07
Nx[4]	1 (1)	0 (0)	1.00
N0[2]	96 (64)	75 (75)	0.08
N1[2]	14 (9)	9 (9)	0.92
N2[2]	18 (12)	8 (8)	0.44
N3[2]	20 (13)	8 (8)	0.18
Pathological Metastatic Stage, No. (%)[1]			0.15
Mx[2]	85 (57)	65 (65)	0.21
M0[2]	60 (40)	35 (35)	0.40
M1[4]	1 (1)	0 (0)	1.00

IQR=interquartile range
[1] ANOVA
[2] Chi-square
[3] T-test
[4] Fisher's exact
[5] Wilcoxon rank sum

TABLE 2. Complications by grade (modified Clavien-Dindo) and type (MSKCC)

Table 2a. Thirty-day post-operative Clavien-Dindo/MSKCC complications by grade for open (n=149) and robotic (n=100) cystectomies

Complication category, %	Grade 1		Grade 2		Grade 3		Grade 4		Grade 5	
	Open	Robot	Open	Robot	Open	Robot	Open	Robot	Open	Robot
Gastrointestinal	27%	15%	23%	26%	4%	5%	0%	0%	0%	0%
Infectious	0	1	14	17	<1	3	5	2	<1	1
Wound	6	0	3	4	3	4	0	0	0	0
Genitourinary	12	11	1	0	3	2	1	1	0	0
Cardiac	2	3	5	1	<1	1	2	0	0	0
Pulmonary	1	0	2	3	0	0	<1	0	0	0
Bleeding	0	0	52	11	0	0	<1	0	0	0
Thromboembolic	0	0	0	0	0	0	0	0	<1	0
Neurological	2	3	<1	1	0	0	<1	1	<1	0
Miscellaneous[1]	7	6	2	2	1	1	1	0	0	0
Surgical	0	0	0	0	2	1	0	0	0	0
Overall[2]	Robot 66%, Open 86%, p<0.01*									

[1] Miscellaneous includes dehydration, acidosis, or other rare complications not appropriate in other categories
[2] Chi-square

Table 2b. Thirty-day post-operative Clavien-Dindo/MSKCC complications for grades 2-5 for open (n=149) and robotic (n=100) cystectomies

Complication category, %	Grades 2-5		
	Open	Robot	p-Value[1]
Gastrointestinal	28%	31%	0.57
Infectious	32	30	0.89
Wound	5	8	0.44
Genitourinary	6	3	0.37
Cardiac	8	2	0.05
Pulmonary	3	3	1.00
Bleeding	52	11	<0.01*
Thromboembolic	9	4	0.14
Neurological	2	2	1.00
Miscellaneous[2]	5	3	0.74
Surgical	2	1	0.65
Overall	69%	42%	<0.01*

[1] Chi-square
[2] Miscellaneous includes dehydration, acidosis, or other rare complications not appropriate in other categories

Table 2c. Thirty-day post-operative Clavien-Dindo/MSKCC minor (grades 1-2) and major (grades 3-5) complications for open (n=149) and robotic (n=100) cystectomies

	Grades 1-2 Minor complications			Grades 3-5 Major complications		
Complication category, %	Open	Robot	p-Value[1]	Open	Robot	p-Value[1]
Gastrointestinal	50%	41%	0.01*	4%	5%	0.76
Infectious	14	18	0.48	6	6	1.00
Wound	9	4	0.20	3	4	0.72
Genitourinary	13	11	0.70	4	3	0.74
Cardiac	7	4	0.42	3	1	0.65
Pulmonary	3	3	1.00	<1	0	1.00
Bleeding	52	11	<0.01*	<1	0	1.00
Thromboembolic	0	0	-	<1	0	1.00
Neurological	3	4	0.72	1	1	1.00
Miscellaneous[2]	9	8	1.00	3	1	0.65
Surgical	0	0	-	2	1	0.65
Overall	85%	66%	<0.01*	19%	10%	0.04*

[1] Chi-square

[2] Miscellaneous includes dehydration, acidosis, or other rare complications not appropriate in other categories

TABLE 3. Regression Analysis for Complication

Table 3a. Univariate analysis for 30-day post-operative complication and all covariates. Covariates with significant p-value <0.25 were selected for multivariable model building.

Dichotomous Variables	Coefficient	Std. Err.	p-Value	OR (95% CI)
Group, robot	-1.14	0.10	<0.01*	0.32 (0.17,0.59)
Sex, female	-0.11	0.33	0.77	0.90 (0.44,1.85)
Race, non-Caucasian	0.13	1.28	0.91	1.14 (0.12,10.38)
Smoking history	0.05	0.38	0.88	1.06 (0.52,2.14)
Location origin, rural	0.33	0.31	0.29	1.039 (0.76,2.52)
Prior abdominal surgery	-0.09	0.28	0.77	0.92 (0.50,1.67)
Prior chemotherapy	0.63	0.75	0.12*	1.87 (0.86,4.10)
Prior pelvic radiation	0.44	0.88	0.44	1.55 (0.51,4.71)
Pathological M stage			0.64	
M0/Mx	Reference	-	-	-
M1	0.71	1.51	0.64	2.03 (0.10,39.87)
Polychotomous Variables				
Age category, years			0.33	
<50	Reference	-	-	-
50-59	0.12	1.02	0.90	1.13 (0. 19,6.70)
60-69	-0.50	0.50	0.54	0.61 (0. 12, 3.05)
70-79	0.25	1.08	0.77	1.29 (0.25,6.71)
≥80	-0.15	0.77	0.86	0.86 (0.15,5.00)
Clinical stage			<0.01*	
cTa/Tcis	Reference	-	-	-
cT1	1.64	0.63	0.01*	5.15 (1.49,17.76)
cT2	2.37	0.61	<0.01*	10.72 (3.23,35.57)
cT3	2.69	1.62	0.10*	14.78 (0.62,351.25)
cT4	3.46	1.57	0.03*	31.67 (1.46,685.30)
Diversion type			0.23*	
Ileal Conduit	Reference	-	-	-
Neobladder	0.72	0.43	0.09*	2.05 (0.89,4.74)
Continent Cutaneous	0.50	1.56	0.75	1.66 (0.08,35.08)
Pathological T stage			0.16*	
pT0/Ta/Tis	Reference	-	-	-
pT1	-0.65	0.29	0.23*	0.52 (0.18,1.52)
pT2	-0.62	0.25	0.18*	0.54 (0.21,1.34)
pT3	0.25	0.50	0.52	1.29 (0.60,2.76)
pT4	0.56	1.07	0.36	1.75 (0.53,5.78)
Pathological N stage			0.97	
N0/Nx	Reference	-	-	-
N1	-0.25	0.40	0.62	0.78 (0.20,2.11)
N2	-0.09	0.46	0.86	0.91 (0.34,2.44)
N3	0.01	0.50	0.99	1.00 (0.38,2.66)
Continuous Variables				
Charlson Comorbidity Score	0.10	0.09	0.246*	1.10 (0.94,1.29)
Preoperative BMI	0.03	0.03	0.34	1.03 (0.97,1.09)
Preoperative creatinine	1.06	1.30	0.02*	2.89 (1.20,6.96)
Preoperative hematocrit	-0.05	0.03	0.06*	0.95 (0.90,1.00)
Operating Time	0.16	0.13	0.02*	1.17 (0.75,1.44)
Length of Stay	0.48	0.17	<0.01*	1.61 (1.31,1.99)

Table 3b. Final multivariable logistic regression model for predictors of 30-day post-cystectomy complication following either open or robotic cystectomy (n=236), p<0.01*

Dichotomous Variables	Odds Ratio	Standard Error	p-Value	95% CI Lower Limit	95% CI Upper Limit
Surgical Group					
Open Cystectomy	Reference	-	-	-	-
Robotic Cystectomy	0.44	0.18	0.049*	0.20	0.99
Prior Chemotherapy	1.17	0.62	0.76	0.42	3.29
Polychotomous Variables					
Clinical Stage			0.11		
Ta/Tcis	Reference	-	-	-	-
T1	2.87	2.04	0.14	0.71	11.55
T2	5.66	4.05	0.02*	1.39	23.03
T3	2.36	4.50	0.65	0.06	99.3
T4	14.84	1.37	0.12	0.51	435.67
Pathological T Stage			0.65		
Ta/Tcis/T0	Reference	-	-	-	-
T1	0.58	0.37	0.39	0.16	2.03
T2	0.48	0.27	0.19	0.16	1.43
T3	0.83	0.39	0.69	0.33	2.09
T4	1.04	0.73	0.96	0.26	4.12
Urinary Diversion Type			0.31		
Ileal Conduit	Reference	-	-	-	-
Neobladder	2.40	1.37	0.13	0.78	7.35
Continent Cutaneous	1.70	2.80	0.32	0.07	42.70
Continuous Variables					
Length of Stay	1.03	0.14	0.01*	1.06	1.61
Preoperative Creatinine	2.25	1.26	0.15	0.75	6.72
Charlson Comorbidity Score	1.12	0.12	0.28	0.91	1.38
Preoperative Hematocrit	0.97	0.04	0.49	0.90	1.05
Operative Time	1.08	0.19	0.68	0.76	1.52

Note: 13 patients with missing values (6 Clinical Stage, 7 Preoperative Creatinine)

TABLE 4. Regression Analysis for Readmission

Table 4a. Univariate analysis for 30-day post-operative readmission and all covariates. Covariates with significant p-value <0.25 were selected for multivariable model building.

Dichotomous Variables	Coefficient	Std. Err.	p-Value	OR (95% CI)
Group, robot	-0.19	0.24	0.51	0.83 (0.47,1.45)
Sex, female	-0.32	0.23	0.33	0.73 (0.39,1.37)
Race, non-Caucasian	1.31	0.92	0.15*	3.73 (0.61,22.80)
Smoking history	-0.45	0.20	0.16*	0.64 (0.34,1.19)
Location origin, rural	0.12	0.28	0.67	1.12 (0.65,1.96)
Prior abdominal surgery	0.45	0.44	0.11*	1.57 (0.90,2.73)
Prior chemotherapy	0.22	0.39	0.49	1.24 (0.67,2.31)
Prior pelvic radiation	0.53	0.74	0.22*	1.70 (0.73,3.99)
Pathological M stage				
M0/Mx	Reference	-	-	-
M1	0.37	1.04	0.72	1.44 (0.19,11.14)
Polychotomous Variables				
Age category, years			0.73	
<50	Reference	-	-	-
50-59	0.15	0.91	0.84	1.17 (0.25,5.41)
60-69	-0.04	0.70	0.96	0.96 (0.23,4.01)
70-79	0.07	0.78	0.93	1.07 (0.26,4.45)
≥80	-0.58	0.46	0.48	0.56 (0.11,2.83)
Clinical stage			0.45	
cTa/Tcis	Reference	-	-	-
cT1	1.23	0.91	0.17*	3.42 (0.58,20.16)
cT2	1.36	0.88	0.12*	3.91 (0.70,21.99)
cT3	0.17	1.74	0.92	1.19 (0.04,36.14)
cT4	1.87	1.12	0.10*	6.48 (0.72,58.22)
Diversion type			<0.01*	
Ileal Conduit	Reference	-	-	-
Neobladder	1.20	0.32	<0.01*	3.31 (1.77,6.20)
Continent Cutaneous	-0.45	1.56	0.77	0.64 (0.30,13.54)
Pathological T stage			0.20*	
pT0/Ta/Tis	Reference	-	-	-
pT1	-0.68	0.29	0.23*	0.51 (0.17,1.54)
pT2	-0.86	0.21	0.08*	0.42 (0.16,1.11)
pT3	-0.72	0.16	0.03*	0.48 (0.25,0.94)
pT4	-0.38	0.32	0.41	0.68 (0.27,1.71)
Pathological N stage			0.70	
N0/Nx	Reference	-	-	-
N1	-0.21	0.41	0.68	0.81 (0.30,2.18)
N2	0.20	0.54	0.65	1.22 (0.51,2.92)
N3	-0.46	0.31	0.34	0.63 (0.24,1.64)
Continuous Variables				
Charlson Comorbidity Score	0.07	0.08	0.30	1.08 (0.94,1.23)
Preoperative BMI	0.07	0.03	0.01*	1.07 (1.01,1.12)
Preoperative creatinine	0.35	0.44	0.26	1.42 (0.77,2.60)
Preoperative hematocrit	<0.01	0.24	0.85	1.00 (0.96,1.05)
Operating Time	0.29	0.13	0.01*	1.34 (1.11,1.61)
Length of Stay	-0.07	0.04	0.07*	0.93 (0.87,1.01)

Table 4b. Final multivariable logistic regression model for predictors of 30-day post-cystectomy readmission following either open or robotic cystectomy (n=248), p<0.01*

Dichotomous Variables	Odds Ratio	Standard Error	p-Value	95% CI Lower Limit	95% CI Upper Limit
Surgical Group					
Open Cystectomy	Reference	-	-	-	-
Robotic Cystectomy	0.70	0.24	0.29	0.36	1.37
Smoking History	0.56	0.21	0.12	0.27	1.15
Race, non-Caucasian	2.56	2.61	0.36	0.35	18.89
Prior Abdominal Surgery	1.38	0.43	0.30	0.75	2.55
Prior Pelvic Radiation	1.52	0.76	0.39	0.58	4.04
Polychotomous Variables					
Urinary Diversion Type			<0.01*		
Ileal Conduit	Reference	-	-	-	-
Neobladder	4.05	1.60	<0.01*	1.87	8.78
Continent Cutaneous	0.22	0.38	0.38	0.01	6.26
Continuous Variables					
Charlson Comorbidity Score	1.22	0.10	0.02*	1.04	1.45
Preoperative BMI	1.07	0.03	0.02*	1.01	1.13
Operative Time	1.37	0.17	0.01*	1.08	1.74
Length of Stay	0.87	0.05	0.01*	0.79	0.97

Note: One patient with missing values (1 Preoperative BMI).

Table 5. 30-day postoperative median cost-to-patient comparison between open and robotic cystectomies by overall and category-specific services rendered, excluding direct robot purchase, amortization, and maintenance cost.

Service Category	Service Subcategory	Surgical Group				p-Value
		Open (n=149)		Robot (n=100)		
		Median $ (IQR)	%	Median $ (IQR)	%	
Operative	OR Services & Supplies[1]	$32502 (29955-37404)	100	$32460 (28328-36255)	100	0.18
	Anesthesia[2]	6049 (5388-6875)	100	5641 (4921-6414)	100	<0.01*
	Category Total	**$38818 (35415-44169)**		**$38247 (33192-42168)**		**0.10**
Diagnostic	Laboratory	$4120 (2729-6043)	100	$1935 (1141-3121)	100	<0.01*
	Pathology	4477 (3475-5428)	100	2630 (2146-3715)	100	<0.01*
	Imaging	1024 (657-2102)	76	484 (270-1217)	51	<0.01*
	Category Total	**$9718 (6588-12623)**		**$5260 (4348-6804)**		**<0.01***
Hospital	Room & Board	$10575 (8460-14805)	98	$9093 (7268-12360)	100	<0.01*
	Inpatient Medications	2701 (1947-4200)	100	1239 (859-2058)	100	<0.01*
	Pharmacy Fees	1958 (1263-2892)	100	1274 (721-2110)	100	<0.01*
	PACU	1217 (838-1570)	86	1173 (770-1617)	99	0.94
	ICU	8900 (4741-14675)	7	3838 (3365-30649)	4	0.19
	GI Services	1080 (-)	<1	1337 (-)	1	0.32
	PT/OT	743 (0-1397)	70	550 (0-1001)	69	0.10
	Speech	725 (683-3575)	5	951 (504-2505)	3	0.91
	Respiratory	1914 (40-4263)	50	243 (0-2660)	31	0.04*
	Clinic	140 (117-280)	13	170 (117-280)	9	0.98
	Professional Fees	263 (255-449)	30	255 (252-271)	16	0.16
	Emergency Room	0	0	1381	1	-
	Category Total	**$18980 (15027-24331)**		**$13666 (11035-19456)**		**<0.01***
Other	Blood Products	$1755 (1142-2728)	52	$1109 (814-1610)	11	0.10
	Doppler/Duplex	885 (831-1296)	28	831 (755-1030)	13	0.69
	Category Total	**$885 (0-2330)**		**$0 (0-0)**		**<0.01***
Overall Cost-to-patient		**$69976 (62410-78785)**	-	**$57336 (50757-66664)**	-	**<0.01***

EXCLUDES direct costs of purchase, amortization, and maintenance contract of robot
[1] Staff, time, operating room space
[2] Staff, time, intraoperative medications and fluids
Note: excludes cardiology, EEG, dialysis services due to an excess of occurrences in open cases

Table 6. Median total cost-to-patient by surgical approach and year of cystectomy

	Open (n=149)			Robot (n=100)			p-Value
Year of Surgery	Median $	IQR	n (%)	Median $	IQR	n (%)	
2009	72116	-	1 (<1)	71290	60832, 72516	4 (4)	0.48
2010	72139	61372, 131299	10 (7)[1]	56614	48563, 63844	25 (25)[1]	<0.01*
2011	74035	67676, 83830	16 (11)	49340	43740, 58905	15 (15)	<0.01*
2012	73561	62116, 83811	23 (15)	54760	48685, 59521	18 (18)	<0.01*
2013	66502	58809, 75377	30 (20)	58549	52687, 64970	20 (20)	0.01*
2014	71939	64717, 81567	44 (30)[1]	61896	55261, 82014	9 (9)[1]	0.08
2015	62995	55715, 72395	25 (17)	76536	61241, 107755	9 (9)	0.07

[1] Statistically significant different proportion of surgeries for given year (2010, 2014; p<0.01 for both)

TABLE 7. Regression Analysis for Cost-to-patient

Table 7a. Univariate analysis for log total cost-to-patient and all covariates. Covariates with significant p-value <0.25 were selected for multivariable model building.

Dichotomous Variables	Coefficient	Std. Err.	p-Value	R^2
Group, robot	-0.19	0.04	<0.01*	0.08
Sex, female	0.01	0.05	0.84	<0.01
Race, non-Caucasian	<0.01	0.15	0.98	0
Smoking history	-0.01	0.05	0.89	<0.01
Location origin, rural	0.10	0.04	0.03*	0.02
Prior abdominal surgery	0.02	0.04	0.61	<0.01
Prior chemotherapy	0.05	0.05	0.28	0.01
Prior pelvic radiation	0.06	0.07	0.41	<0.01
Pathological M stage				
M0/Mx	Reference	-	-	-
M1	0.10	0.19	0.60	<0.01
Polychotomous Variables				
Age category, years			0.78	0.01
<50	Reference	-	-	-
50-59	-0.07	0.12	0.55	-
60-69	-0.11	0.11	0.33	-
70-79	-0.08	0.11	0.47	-
≥80	-0.14	0.12	0.26	-
Clinical stage			0.01*	0.01
cTa/Tcis	Reference	-	-	-
cT1	0.20	0.10	0.04*	-
cT2	0.22	0.10	0.02*	-
cT3	0.70	0.21	<0.01*	-
cT4	0.37	0.15	0.02*	-
Diversion type			0.02*	0.02
Ileal Conduit	Reference	-	-	-
Neobladder	0.14	0.05	0.01*	-
Continent Cutaneous	0.26	0.23	0.26	-
Pathological T stage			0.04*	0.04
pT0/Ta/Tis	Reference	-	-	-
pT1	0.04	0.08	0.65	-
pT2	-0.14	0.07	0.04*	-
pT3	-0.01	0.05	0.88	-
pT4	0.13	0.07	0.07*	-
Pathological N stage			0.91	<0.01
N0/Nx	Reference	-	-	-
N1	-0.03	0.07	0.68	-
N2	0.04	0.07	0.67	-
N3	-0.02	0.07	0.72	-
Continuous Variables				
Charlson Comorbidity Score	0.10	0.04	0.03*	0.01
Preoperative BMI	0.01	<0.01	<0.01*	0.04
Preoperative creatinine	0.14	0.05	<0.01*	0.04
Preoperative hematocrit	>-0.01	<0.01	0.78	<0.01
Operating Time	0.06	0.01	<0.01*	0.07

Length of Stay	0.05	<0.01	<0.01*	0.69

Table 7b. Final multivariable linear regression model for 30-day post-cystectomy log total cost-to-patient[1] (n=242), p<0.01*, Adjusted R^2=0.83

Dichotomous Variables	Coefficient	Standard Error	p-Value	95% CI Lower Limit	95% CI Upper Limit
Surgical Group					
Open Cystectomy	Reference	-	-	-	-
Robotic Cystectomy	-0.18	0.02	<0.01*	-0.22	-0.14
Prior Chemotherapy	0.04	0.02	0.08	0	0.09
Polychotomous Variables					
Age Category			0.03*		
<50	Reference	-	-	-	-
50-59	-0.11	0.05	0.03*	-0.22	-0.01
60-69	-0.10	0.05	0.04*	-0.20	-0.003
70-79	-0.13	0.05	0.01*	-0.23	-0.03
>=80	-0.18	0.06	<0.01*	-0.30	-0.06
Clinical Stage			0.88		
Ta/Tcis	Reference	-	-	-	-
T1	0.03	0.04	0.52	-0.06	0.11
T2	0.02	0.04	0.57	-0.60	0.11
T3	0.04	0.09	0.66	-0.14	0.23
T4	-0.02	0.07	0.73	-0.16	0.11
Urinary Diversion Type			0.15		
Ileal Conduit	Reference	-	-	-	-
Neobladder	0.01	0.03	0.76	-0.04	0.06
Continent Cutaneous	0.20	0.10	0.05*	0	0.40
Pathological T Stage			<0.01*		
Ta/Tcis/T0	Reference	-	-	-	-
T1	-0.06	0.04	0.13	-0.13	0.02
T2	-0.06	0.03	0.07	-0.12	<0.01
T3	-0.01	0.02	0.55	-0.06	0.03
T4	0.08	0.03	0.02*	0.02	0.14
Continuous Variables					
Charlson Comorbidity Score	0.02	0.01	<0.01*	0.01	0.04
Preoperative BMI	0.004	<0.01	0.03*	<0.01	0.01
log (Operating Time)[1]	0.31	0.05	<0.01*	0.21	0.40
Length of Stay	0.04	<0.01	<0.01*	0.04	0.05

Note: Seven patients excluded for missing values (6 Clinical Stage, 1 Preoperative BMI)

[1] Log here is natural log

APPENDICES

Table A: Charlson Comorbidity Score (CCS) utilized to characterize pre-operative comorbidity scores. Each comorbidity a patient has adds the corresponding scoring point to their total score. Increased total score indicates increased comorbidity severity. There is no total score upper limit.[13]

Point(s)	Comorbidity	
0	Age <50 years	
1	Age 50-59 years Myocardial infarction Congestive heart failure Peripheral vascular disease Cerebrovascular disease Dementia	Chronic pulmonary disease Connective tissue disease Ulcer disease Mild liver disease Diabetes without end organ damage
2	Age 60-69 years Hemiplegia Moderate or severe renal disease	Diabetes with end organ damage Any malignancy
3	Age 70-79 years Moderate or severe liver disease (e.g., cirrhosis with ascites)	
4	Age 80-89 years	
5	Age 90-99 years	
6	Metastatic solid tumor or AIDS	

Adapted from source:

Charlson, M., Szatrowski, T. P., Peterson, J. et al.: Validation of a combined comorbidity index. J Clin Epidemiol, **47:** 1245, 1994

Table B: Modified Clavien-Dindo Post-Operative Complication Grading System

Grade	Definition
Grade 0	No event observed
Grade 1	Complication not requiring intervention, except antiemetics, antipyretics, analgesics, diuretics, electrolytes, bedside wound care, and physical therapy
Grade 2	Complication requiring blood transfusions, total parenteral nutrition, or pharmacologic therapy beyond those listed under Grade I
Grade 3	Complication requiring surgical, endoscopic or radiological intervention
Grade 4	Life-threatening complication requiring Intensive Care Unit management
Grade 5	Death of patient

Adapted from source:

Dindo D, Demartines N, Clavien P-A. Classification of Surgical Complications. *Ann Surg*. 2004;240(2):205-213.

Shabsigh A, Korets R, Vora KC, et al. Defining early morbidity of radical cystectomy for patients with bladder cancer using a standardized reporting methodology. *Eur Urol*. 2009;55(1):164-174.

Table C: Memorial Sloan-Kettering Cancer Center (MSKCC) Complication Categories

Category (% of category total)	**Complication (frequency no.*)**
Gastrointestinal (%, n)	Ileus** (n), small bowel obstruction (n), constipation*** (n), clostridium difficile colitis (n), gastrointestinal bleeding (n), emesis (n), anastomotic bowel leak (n), diarrhea (n)
Infectious (%, n)	Fever of unknown origin (n), abscess (n), urinary tract infection (n), sepsis (n), urosepsis (n), pyelonephritis (n), diverticulitis (n), cholecystitis (n)
Wound (%, n)	Wound seroma (n), Wound infection (n), Wound dehiscence (n)
Genitourinary (%, n)	Renal failure (n), ureteral obstruction (n), urinary leak (n), urinary fistula (n), urinary retention (n), parastomal hernia (n), stomal ischemia (n), hematuria (n)
Cardiac (%, n)	Arrhythmia (n), myocardial infarction (n), hypertension (n), congestive heart failure (n), angina (n), hypotension (n)
Pulmonary (%, n)	Atelectasis (n), pneumonia (n), respiratory distress (n), pneumothorax (n), pleural effusion (n)
Bleeding (%, n)	Anemia requiring transfusion (n), post-operative bleed other than GI (n), wound hematoma (n)
Thromboembolic (%, n)	Deep venous thrombosis (n), pulmonary embolism (n), superficial phlebitis (n)
Neurological (%, n)	Peripheral neuropathy (n), cerebrovascular accident (n), transient ischemic attack (n), delirium (n), vertigo (n), presyncope, (n), syncope (n)
Miscellaneous (%, n)	Decubitus ulcer (n), dermatitis (n), acidosis (n), lymphocele (n), dehydration (n), other rare complications (n)
Surgical (%, n)	Vascular injury (n), bowel injury (n), retained foreign body (n)

* Patients experiencing multiple complications of the same type are counted more than once.

** Ileus = post-operative nausea or vomiting associated with abdominal distension requiring cessation of oral intake and intravenous fluid support and/or nasogastric tube (NGT) placement, or the intolerance of oral intake by postoperative day 5 resulting in patient fasting regardless of NGT placement or antiemetic medication use.

*** Constipation = inability to have a bowel movement by post-operative day 5 with no signs of ileus or small bowel obstruction.

Adapted from source:

Shabsigh A, Korets R, Vora KC, et al. Defining early morbidity of radical cystectomy for patients with bladder cancer using a standardized reporting methodology. *Eur Urol*. 2009;55(1):164-174.