

Original article

Robotic vs. open cystectomy: How length-of-stay differences relate conditionally to age

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Abstract

Objectives: The length-of-stay (LOS) benefit of minimally invasive cystectomy varies in the published literature, potentially because of subgroup effects. Here, we investigated the effect of minimally invasive cystectomy on LOS among different age groups.

Methods and materials: Adult patients who underwent cystectomy (open or minimally invasive) from January 1, 2012, to December 31, 2016, were identified from the National Surgical Quality Improvement Program database. Multivariable linear regression was used to evaluate the adjusted association between the surgical approach and LOS after stratifying patients by age (40–64, 65–79, and ≥80 years). A sensitivity analysis was performed after multiple imputation by using age as a continuous variable with a third-order polynomial term.

Results: Of the 5,561 patients identified, 640 underwent minimally invasive cystectomy and 4,921 had open cystectomy. The unadjusted analysis showed that minimally invasive cystectomy was associated with a shorter mean LOS compared with the open approach (8.0 vs. 9.7 days; $P < 0.001$). The predicted difference in LOS between the 2 approaches was 0.72 days (95% confidence interval (CI), –0.28 to 1.72; $P = 0.16$) for patients aged 40 to 64 years, 1.48 days (95% CI, 0.73–2.23; $P < 0.001$) for 65 to 79 years, and 2.56 days (95% CI, 0.84–4.29; $P = 0.01$) for ≥80 years favoring the minimally invasive approach. The sensitivity analysis did not materially change the results.

Conclusions: Older patients may derive more LOS benefit from minimally invasive approaches than younger patients. Given the greater expense associated with the minimally invasive approach, an age-adapted strategy to using this technology may be reasonable. © 2019 Elsevier Inc. All rights reserved.

Keywords: Bladder cancer; Cystectomy; Length of stay; Robotic surgery procedures

Abbreviations: COPD, chronic obstructive pulmonary disease; CPT, Current Procedural Terminology; LOS, length of stay; NSQIP, National Surgical Quality Improvement Program

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1. Introduction

Cystectomy with urinary diversion is associated with characteristically high perioperative morbidity, with hospitalizations often exceeding 7 days [1,2]. To expedite discharge from the hospital, minimally invasive approaches to cystectomy have been adopted in recent decades [3,4]. However, the evidence regarding length-of-stay (LOS)

differences between laparoscopic and open cystectomy is mixed; 1 randomized trial showed a modest benefit [5] but others did not [6,7]. One emerging hypothesis for this discordant observation is that subsets of the population, such as older patients, may differentially benefit from minimally invasive approaches [1,8].

Several plausible explanations may account for variations in LOS by age. Compared with younger patients, older patients often have more pain, have a slower return of bowel function, require more physical therapy, and generally have a more difficult transition to independence after cystectomy [9]. Although younger patients are more apt to recovery from open or minimally invasive cystectomy in about the same amount of time, minimally invasive approaches may mitigate the impact of surgery on the functional status of older patients. LOS benefits of minimally invasive surgery in the elderly have been demonstrated in contemporary studies assessing major oncological procedures outside of urology [10–13]. One small retrospective study reported a LOS benefit after minimally invasive cystectomy for patients older than 75 years [14]. We hypothesized that older patients derived more benefit from a minimally invasive approach than younger patients, but studies explicitly evaluating this question are lacking.

In this context, we tested the hypothesis that the effect of minimally invasive approaches on LOS after cystectomy relates conditionally to patient age. We hypothesized that with increasing age, differences in LOS between open and minimally invasive approaches would increase. By delineating which subgroups of the population benefit most from laparoscopy, we aimed to guide the development of rational strategies for the efficient use of emerging surgical technologies.

2. Methods

This study was exempted by the Mayo Clinic Institutional Review Board.

2.1. Data source

We retrospectively reviewed data from the 2012 to 2016 participant use files of the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database. The NSQIP is a prospective, multi-institutional database that collects data in a Health Insurance Portability and Accountability Act–compliant manner on more than 150 variables by trained surgical clinical abstractors who are randomly assigned patients for review. Thirty-day postoperative clinical outcomes are reviewed for surgical patients at participating institutions. To ensure that the data collected are of high quality, NSQIP conducts an inter rater reliability audit of various participating sites that randomly reviews multiple charts to identify reporting errors (error rate is approximately 2%) [15].

2.2. Study population

We used Current Procedural Terminology (CPT) codes 51570, 51575, 51580, 51585, 51590, 51595, and 51596 to identify a cohort of patients older than 40 years who underwent cystectomy. We excluded patients with benign disease, those who underwent combined procedures that are not typically performed with a cystectomy (e.g., nephroureterectomy), and patients with metastatic disease (Fig. 1). Because no CPT code exists for minimally invasive cystectomy, we used concurrent CPT codes that indicate laparoscopy or robotic approaches being used as a principal or concurrent procedure [16]. A list of these codes is shown in the Appendix.

2.3. Variables measured

We collected data about patient characteristics (e.g., age, sex, race/ethnicity, weight, height, functional status), preoperative risk factors (e.g., body mass index, smoking history, alcohol use), American Society of Anesthesiologists classification, preoperative laboratory values, chronic corticosteroid use, and comorbidities (e.g., history of hypertension, hyperlipidemia, chronic kidney disease, cerebrovascular accident, congestive heart failure, chronic obstructive pulmonary disease [COPD], diabetes mellitus requiring therapy, acute coronary syndrome, bleeding

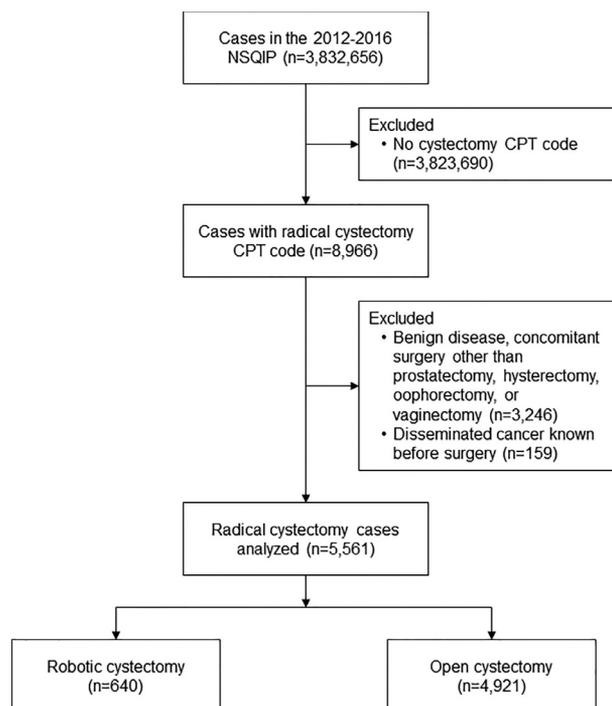


Fig. 1. Flowchart of patients undergoing radical cystectomy and subsequent differentiation between open and robotic approaches. CPT = Current Procedural Terminology; NSQIP = National Surgical Quality Improvement Program.

disorder). Procedural information included the date of procedure, anesthesia used, length of operation, intraoperative complications, surgical approach (minimally invasive vs. open cystectomy), and urinary diversion type. Postoperative characteristics included the LOS, urinary tract infection, pneumonia, superficial surgical site infection, pulmonary embolism, deep vein thrombosis and thrombophlebitis, sepsis, and myocardial infarction. The primary outcome was hospital LOS, which was determined as the period from the day of surgery through the day of discharge.

2.4. Power and sample size

Using thresholds established by Cohen [17], the means between the 2 groups needed to differ by 0.2 standard deviations or more to qualify as a “small effect.” The SDs for LOS in the published literature are highly variable but often are about 7. Therefore, before the analysis, we specified that if the difference in LOS did not exceed 1.4 days, it would not be clinically meaningful, even if statistically significant. Using this effect size, we determined that a sample size of approximately 650 patients in each group had 95% power to detect a difference of 0.2 SDs, or 1.4 days, at a significance level of 0.05 for a 2-sample means test.

2.5. Statistical methods

Patient characteristics were summarized with mean standard deviation (SD) or count (percentage), and the minimally invasive and open cystectomy were compared with the 2-sample *t* test or χ^2 test. We used linear regression to assess the unadjusted association between patient characteristics and LOS. We then used a multivariable linear regression model to evaluate the adjusted association. The exposure variable was age, stratified into 3 groups: 40 to 64, 65 to 79, and ≥ 80 years. We tested the interaction effect between age and surgical approach in the multivariable model. Other covariates included year of operation, body mass index, diabetes mellitus, history of smoking, functional status, history of COPD, history of chronic heart disease, transfusion, superficial surgical site infection, wound disruption, pneumonia, pulmonary embolism, progressive renal insufficiency, urinary tract infection, myocardial infarction, deep vein thrombosis, and neobladder. Because we had minimal missing data, we performed a complete case analysis.

2.6. Sensitivity analysis

Because the use of cutoffs for age assumes that the relationship between age and LOS is flat within each category, we conducted a sensitivity analysis with age as a continuous variable. We also tested departures from the linearity assumption by using restricted cubic splines and conventional polynomials. Tests of model fit indicated that a cubic

function best parameterized the pattern of LOS in the data. The interaction of age and procedure was modeled with age centered at the mean value to reduce multicollinearity. To reduce potential bias from an arbitrary missing-value pattern, we fit this model after multiple imputation by using chained equations with 20 imputed data sets. We considered any missing data to be missing at random because “missingness” was considered to be unrelated to any item in the study, including outcome. Statistical analyses were conducted using R 3.4.4 (R Project for Statistical Computing), and *P* values < 0.05 were considered significant.

3. Results

We identified 640 and 4,921 patients who underwent minimally invasive or open cystectomy, respectively. Baseline characteristics are summarized in Table 1; there were no significant differences between the 2 groups with respect to baseline characteristics (Table 1).

On unadjusted analysis, patients who underwent a minimally invasive cystectomy had a 1.7-day shorter mean LOS than the open cohort (95% CI, 1.2–2.4; $P < 0.001$). Factors associated with a mean difference in LOS included patient age, COPD, congestive heart failure, preoperative hemoglobin, and functional status (Table 2). In a supplemental analysis, we observed that a $> 10\%$ weight loss in the 6 months before surgery and a history of other malignancy also were associated with a mean difference in LOS (Supplemental Table 1). As expected, perioperative complications such as need for blood transfusions, deep vein thrombosis or pulmonary embolism, and reoperations were associated with greater LOS. Older patients had a higher incidence of morbid complications (e.g., myocardial infarction, pneumonia) than younger patients. Supplemental Table 2 includes complications for each age group.

3.1. Multivariable model

In 40- to 64-year-old patients, the mean difference in LOS did not meet the prespecified criteria for clinical significance or statistical significance (mean difference, 0.72 days; 95% CI, -0.28 to 1.72 ; $P = 0.16$). In contrast, for older patients, the mean differences in LOS did meet the prespecified criteria for clinical significance. For 65- to 80-year-olds, the mean difference was 1.48 days (95% CI, 0.73 – 2.23 ; $P \leq 0.001$); for ≥ 80 -year-olds, the difference was 2.56 days (95% CI, 0.84 – 4.29 ; $P = 0.01$) (Fig. 2). Of note, the younger cohort included only 184 male and 21 female patients who underwent laparoscopic cystectomy, which makes it difficult to definitively identify the true LOS benefit in this age group.

3.2. Sensitivity analysis

To test whether the use of age cutoffs influenced the observed relationship between age and LOS, we performed

Table 1
Baseline patient characteristics.

Characteristic	All patients (N = 5,561)	Open cystectomy (n = 4,921)	Minimally invasive cystectomy (n = 640)	P value
Length of stay, d				<0.001
Mean (SD)	9.52 (7.38)	9.72 (7.51)	7.96 (6.10)	
Median (IQR)	7 (6–10)	7 (6–10)	6 (5–8)	
Y of operation, no. (%)				<0.001
2012	599 (10.8)	567 (11.5)	32 (5.0)	
2013	926 (16.7)	821 (16.7)	105 (16.4)	
2014	1,144 (20.6)	1,006 (20.4)	138 (21.6)	
2015	1,261 (22.7)	1,085 (22.0)	176 (27.5)	
2016	1,631 (29.3)	1,442 (29.3)	189 (29.5)	
Age, y				0.10
Mean (SD)	68.75 (9.66)	68.83 (9.71)	68.16 (9.27)	
Median (IQR)	69 (62–76)	70 (62–76)	69 (63–75)	
Race/ethnicity, no. (%)				<0.001
White	4,214 (75.8)	3,652 (74.2)	562 (87.8)	
Black	227 (4.1)	197 (4.0)	30 (4.7)	
Other	82 (1.5)	71 (1.4)	11 (1.7)	
Unknown or not reported	1,038 (18.7)	1,001 (20.3)	37 (5.8)	
Body mass index, kg/m ²				0.41
Missing data, no.	27	26	1	
Mean (SD)	28.52 (5.61)	28.55 (5.70)	28.35 (4.90)	
Median (IQR)	27.88 (14.32–69.27)	27.89 (14.32–69.27)	27.82 (16.81–51.25)	
Diabetes mellitus, no. (%)				0.08
Not insulin dependent	740 (13.3)	666 (13.5)	74 (11.6)	
Insulin dependent	377 (6.8)	322 (6.5)	55 (8.6)	
History of smoking, No. (%)	1,331 (23.9)	1,158 (23.5)	173 (27.0)	0.06
History of chronic obstructive pulmonary disease, no. (%)	431 (7.8)	372 (7.6)	59 (9.2)	0.16
History of congestive heart failure, no. (%)	35 (0.6)	31 (0.6)	4 (0.6)	>0.99
Transfusion, no. (%)	80 (1.4)	74 (1.5)	6 (0.9)	0.34
Functional status, no. (%)				0.07
Independent	5,443 (97.9)	4,810 (97.7)	633 (98.9)	
Partially or totally dependent	109 (2.0)	103 (2.1)	6 (0.9)	
Preoperative albumin g/dl				<0.001
Missing data, no.	2,055	1,907	148	
Mean (SD)	3.94 (0.51)	3.93 (0.51)	4.04 (0.48)	
Median (IQR)	4.00 (3.7–4.3)	4.00 (3.7–4.3)	4.10 (3.8–4.3)	
Preoperative hematocrit g/dl				0.81
Missing data, no.	115	105	10	
Mean (SD)	37.90 (5.65)	37.90 (5.63)	37.96 (5.79)	
Median (IQR)	38.3 (34.0–42.0)	38.3 (34.0–42.0)	38.0 (33.8–42.2)	
Superficial surgical site infection, no. (%)	322 (5.8)	305 (6.2)	17 (2.7)	<0.001
Wound disruption, no. (%)	137 (2.5)	135 (2.7)	2 (0.3)	<0.001
Pneumonia, no. (%)	155 (2.8)	140 (2.8)	15 (2.3)	0.55
Pulmonary embolism, no. (%)	88 (1.6)	77 (1.6)	11 (1.7)	0.90
Progressive renal insufficiency, no. (%)	101 (1.8)	90 (1.8)	11 (1.7)	0.97
Urinary tract infection, no. (%)	466 (8.4)	392 (8.0)	74 (11.6)	0.003
Myocardial infarction, no. (%)	86 (1.5)	76 (1.5)	10 (1.6)	>0.99
Deep vein thrombosis requiring therapy, no. (%)	130 (2.3)	117 (2.4)	13 (2.0)	0.68
Reoperation, no. (%)	287 (5.2)	271 (5.5)	16 (2.5)	0.002
Readmission, no. (%)	1,112 (20.0)	964 (19.6)	148 (23.1)	0.04
Neobladder, no. (%)	895 (16.1)	812 (16.5)	83 (13.0)	0.03

Abbreviation: IQR = interquartile range.

Table 2
Bivariate association.

Variable	Comparison	Estimated difference in LOS, d (95% CI)	P value
Laparoscopy	Laparoscopy vs. open	−1.76 (−2.37 to −1.16)	<0.001
Race/ethnicity	Black vs. other	1.76 (−0.07 to 3.60)	0.06
	Unknown vs. other	2.84 (1.21–4.48)	<0.001
	White vs. other	−0.46 (−2.05 to 1.13)	0.57
Body mass index	Per 1-unit increase	0.00 (−0.03 to 0.03)	>0.99
Diabetes mellitus	No vs. insulin	−0.46 (−1.23 to 0.32)	0.25
	Noninsulin vs. insulin	−0.15 (−1.06 to 0.77)	0.75
History of smoking	Yes vs. no	0.13 (−0.32 to 0.59)	0.57
History of chronic obstructive pulmonary disease	Yes vs. no	1.66 (0.93–2.38)	<0.001
History of congestive heart failure	Yes vs. no	3.70 (1.25–6.15)	0.003
Transfusion	Yes vs. no	5.20 (3.58–6.83)	<0.001
Preoperative hemoglobin	Per 1-unit increase	−2.56 (−3.03 to −2.10)	<0.001
Preoperative albumin	Per 1-unit increase	−0.10 (−0.14 to −0.07)	<0.001
Superficial surgical site infection	Yes vs. no	4.35 (3.52–5.17)	<0.001
Wound disruption	Yes vs. no	8.04 (6.81–9.28)	<0.001
Pneumonia	Yes vs. no	9.35 (8.19–10.50)	<0.001
Pulmonary embolism	Yes vs. no	4.10 (2.55–5.65)	<0.001
Progressive renal insufficiency	Yes vs. no	5.04 (3.59–6.48)	<0.001
Urinary tract infection	Yes vs. no	1.87 (1.18–2.57)	<0.001
Myocardial infarction	Yes vs. no	6.96 (5.40–8.52)	<0.001
Deep vein thrombosis requiring therapy	Yes vs. no	5.40 (4.12–6.67)	<0.001
Reoperation	Yes vs. no	11.89 (11.07–12.71)	<0.001
Readmission	Yes vs. no	−1.63 (−2.11 to −1.15)	<0.001
Neobladder	Yes vs. no	−0.16 (−0.68 to 0.37)	0.56
Functional status	Partially or totally dependent vs. independent	4.09 (2.70–5.48)	<0.001
Age, polynomial with degree = 3, centered at mean value (68.6)	(Age _i − mean.age)	0.09 (0.05–0.12)	<0.001
	(Age _i − mean.age) ²	0.002 (0.00004–0.004)	<0.001
	(Age _i − mean.age) ³	−0.00007 (−0.0002 to 0.00005)	0.29
Approach × age ^a	LC × (age 65–79)	−0.77 (−2.02 to 0.48)	0.23
	LC × (age ≥80)	−1.88 (−3.87 to 0.11)	0.06

Abbreviations: LC = laparoscopic cystectomy; LOS = length of stay.

^a Test of interaction, $P = 0.16$.

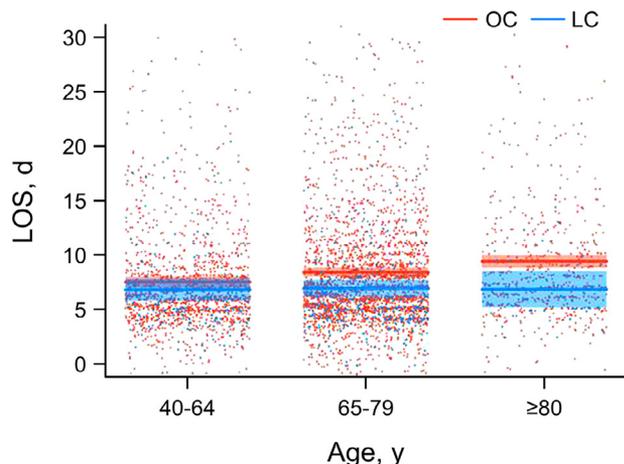


Fig. 2. Marginal plot from the adjusted model shows the predicted LOS for LC (blue) and OC (red). Individual points reflect the predicted value for each patient when setting all covariates to their mean for continuous variables or the mode for categorical variables. Shaded areas indicate the 95% CIs. LC = laparoscopic cystectomy; LOS = length of stay; OC = open cystectomy.

a sensitivity analysis in which the age-treatment interaction was tested by using age as a continuous variable, performing multiple imputation for missing data, and using a cubic polynomial term to model the relationship nonlinearly. The estimates for the age-treatment interaction are shown in Table 2. Although the difference in LOS increased with age, the various methods of analysis did not show a statistically significant interaction. The same trend was observed as before for clinically meaningful and statistically significant differences in LOS: for a 45-year-old patient (1.27 days; 95% CI, −1.52 to 4.06; $P = 0.37$), 65-year-old patient (1.14 days; 95% CI, 0.39–1.89; $P = 0.003$), and 85-year-old patient (2.01 days; 95% CI, 0.07–3.94; $P = 0.04$). A marginal plot for this model is shown in Fig. 3.

4. Discussion

In this multicenter, retrospective study of cystectomies recorded in the NSQIP database, we showed that laparoscopic approaches to cystectomy reduced LOS by

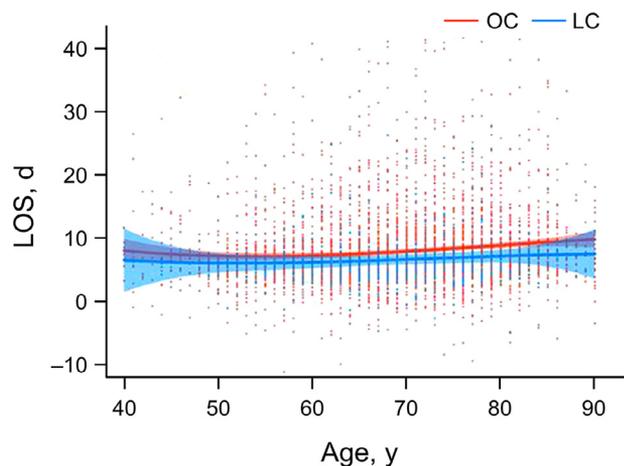


Fig. 3. Marginal plot from the sensitivity analysis in the adjusted model showing the predicted LOS for LC (blue) and OC (red). Individual points indicate the predicted value for each patient after setting all covariates to their mean for continuous variables or the mode for categorical variables. Shaded areas indicate the 95% CIs. LC = laparoscopic cystectomy; LOS = length of stay; OC = open cystectomy.

1 to 2 days in patients older than 65 years and by an unknown, likely smaller amount for younger patients. This finding, which was robust to varying definitions of age (categorical vs. continuous), may help lay the foundation for an age-adapted approach to the surgical planning of cystectomy.

Data from previous randomized trials suggest that minimally invasive approaches do not dramatically reduce LOS. In the Memorial trial [6], the mean LOS was 8 days in both groups, but the robotic arm in the Randomised Open versus Robotic Cystectomy (RAZOR) trial showed a slight advantage (6 vs. 7 days; $P = 0.02$) [5]. However, participants in clinical trials are highly selected subpopulations of patients with cancer, usually treated at centers of excellence, and may not broadly represent the benefits of laparoscopy observed in everyday clinical practice. Furthermore, these estimates represent measures of central tendency for all trial participants and do not exclude the possibility that certain subsets would have responded differently to the exposure, a concept known as effect modification. Because older patients generally have a more difficult transition to independence after cystectomy and because laparoscopy is intended to minimize the impact of surgery on function, age is an expected modifier of the effect of surgical approach on LOS after cystectomy [8,9].

Although minimally invasive approaches to cystectomy have been associated with shorter LOS in some early studies [3,18,19], the beneficial effect of laparoscopy may be mitigated by enhanced recovery pathways in more modern series, particularly for younger patients. These enhanced pathways, which aim to expedite convalescence through the standardization of perioperative best practices, are now

ubiquitous and likely have a large role in mitigating the benefits of laparoscopy with regard to LOS. The benefits of enhanced recovery pathways are especially evident in younger patients, for whom the rate-limiting step for discharge is often the return of bowel function [20]. In older patients, restoration of bowel function is still an important postoperative milestone, but many older patients often have additional impediments to early discharge such as pain, physical therapy requirements, and delays in placement into rehabilitation centers. Older patients can still benefit from enhanced recovery programs because these programs facilitate the expedited return of bowel function, facilitate ambulation, and decrease pain medication requirements, but other factors such as functional mobility may have greater influence on the course of their hospital stay. To the extent that enhanced recovery pathways can expedite discharge for a given patient, laparoscopy has diminishing returns.

These findings may have important economic implications as well. In several previous cost studies, the fully allocated costs of robotic cystectomy, both fixed and variable, were offset by a shorter hospital LOS [19,21]. However, if LOS benefits are not realized in younger patients, then this value proposition dissipates rapidly, as observed in the Memorial trial [6]. One potential solution is an age-adapted algorithm for surgical decision-making; younger patients should be counseled that the large benefits in LOS observed in early retrospective studies have not been substantiated in randomized trials or in large multi-institutional quality registries. Alternatively, Medicare-aged patients should be counseled that evidence from the current study supports a modest, 1- to 2-day decrease in LOS. This initiative may promote more efficient disease management, in that younger patients may avoid longer operative times and greater costs associated with laparoscopy without any material improvements in perioperative outcomes, with the one possible exception of blood transfusions [5,6]. Additionally, surgeons who may not have strong preferences for the surgical approach may be able to apply these data to the decision-making processes.

This study has certain important limitations. First, residual confounding, particularly by unmeasured confounders, may bias the effect estimates. The NSQIP database does not include cancer grade or stage, urinary diversion approach, implementation of a postoperative enhanced recovery protocol, or alvimopan administration; therefore, we could not control for these factors in our analysis. Specifically, implementation of various components of protocols for enhanced recovery after surgery can significantly affect LOS, and as such, the inability to include these data is a major limitation of this study. Although additional preoperative variables could have been used, we chose the covariates before fitting the model based on subject matter knowledge. Second, even though the data are collected prospectively, our study was a retrospective analysis of the

data that may be prone to bias. Nevertheless, the original data collection methods used by NSQIP abstractors ensures that the data collected are of high quality, and quality is verified by regular audits by the NSQIP. Third, the primary exposure of interest was categorized into clinically relevant age groups (non-Medicare and Medicare). However, with categorization of continuous variables, several assumptions were made, including homogeneity within categories (as described in Section 2) [22]. However, we repeated the analysis by using age as a continuous variable, nonlinear modeling methods, and multiple imputation, and we found little evidence that categorization of age, departures from linearity assumptions, or missingness substantially affected the interpretation of the data. Fourth, current NSQIP policies prohibit the sharing of hospital or clinician identifiers, which prevents the ability to account for clustering of outcomes. Fifth, these data are from participating NSQIP institutions and do not constitute a statistically valid nationally representative sample. Sixth, surgeons likely have some inherent biases that affect their decisions to use or exclude a specific approach for a given patient. Lastly, in a supplemental analysis (Supplemental Table 3), we showed that significantly fewer women underwent laparoscopic cystectomy compared with men, especially in the oldest age groups (≥ 80 years), which limits the generalizability of this study.

Despite these limitations, this study provides evidence that the beneficial effect of laparoscopy on LOS after cystectomy relates conditionally to age. This study lays the foundation for an age-adapted approach that may promote more effective disease management at institutions where both procedures are performed.

4.1. Conclusions

This study showed that older patients may experience greater benefit from minimally invasive approaches to cystectomy than younger patients in terms of hospital LOS. When considering this finding in the context of the expense associated with the minimally invasive approach, an age-adapted strategy to the use of this technology may benefit patients and hospital systems.

Supplementary materials

Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1016/j.urolonc.2019.01.028>.

References

- [1] Sood A, Kachroo N, Abdollah F, Sammon JD, Loppenberg B, Jindal T, et al. An evaluation of the timing of surgical complications following radical cystectomy: data from the American College of Surgeons National Surgical Quality Improvement Program. *Urology* 2017;103:91–8.
- [2] Johnson SC, Smith ZL, Golan S, Rodriguez JF 3rd, Smith ND, Steinberg GD. Temporal trends in perioperative morbidity for radical cystectomy using the National Surgical Quality Improvement Program database. *Urol Oncol* 2017;35:659.e13–e19.
- [3] Tang K, Xia D, Li H, Guan W, Guo X, Hu Z, et al. Robotic vs. open radical cystectomy in bladder cancer: a systematic review and meta-analysis. *Eur J Surg Oncol* 2014;40:1399–411.
- [4] Tan HJ, Wolf JS Jr., Ye Z, Wei JT, Miller DC. Population-level comparative effectiveness of laparoscopic versus open radical nephrectomy for patients with kidney cancer. *Cancer* 2011;117:4184–93.
- [5] Parekh DJ, Reis IM, Castle EP, Gonzalgo ML, Woods ME, Svatek RS, et al. Robot-assisted radical cystectomy versus open radical cystectomy in patients with bladder cancer (RAZOR): an open-label, randomised, phase 3, non-inferiority trial. *Lancet* 2018;391:2525–36.
- [6] Bochner BH, Dalbagni G, Sjoberg DD, Silberstein J, Keren Paz GE, Donat SM, et al. Comparing open radical cystectomy and robot-assisted laparoscopic radical cystectomy: a randomized clinical trial. *Eur Urol* 2015;67:1042–50.
- [7] Nix J, Smith A, Kurpad R, Nielsen ME, Wallen EM, Pruthi RS. Prospective randomized controlled trial of robotic versus open radical cystectomy for bladder cancer: perioperative and pathologic results. *Eur Urol* 2010;57:196–201.
- [8] Pietzak EJ, Hwang WT, Malkowicz SB, Guzzo TJ. Factors influencing the length of stay after radical cystectomy: implications for cancer care and perioperative management. *Ann Surg Oncol* 2014;21:4383–9.
- [9] Roghmann F, Sukumar S, Ravi P, Trinh VQ, Meskawi M, Ghani KR, et al. Radical cystectomy in the elderly: national trends and disparities in perioperative outcomes and quality of care. *Urol Int* 2014;92:27–34.
- [10] Kwon IG, Cho I, Guner A, Kim HI, Noh SH, Hyung WJ. Minimally invasive surgery as a treatment option for gastric cancer in the elderly: comparison with open surgery for patients 80 years and older. *Surg Endosc* 2015;29:2321–30.
- [11] Li J, Shen Y, Tan L, Feng M, Wang H, Xi Y, et al. Is minimally invasive esophagectomy beneficial to elderly patients with esophageal cancer? *Surg Endosc* 2015;29:925–30.
- [12] Liu CA, Huang KH, Chen MH, Lo SS, Li AF, Wu CW, et al. Comparison of the surgical outcomes of minimally invasive and open surgery for octogenarian and older compared to younger gastric cancer patients: a retrospective cohort study. *BMC Surg* 2017;17:68.
- [13] Robinson CN, Balentine CJ, Marshall CL, Wilks JA, Anaya D, Artinyan A, et al. Minimally invasive surgery improves short-term outcomes in elderly colorectal cancer patients. *J Surg Res* 2011;166:182–8.
- [14] Winters BR, Bremjit PJ, Gore JL, Lin DW, Ellis WJ, Dalkin BL, et al. Preliminary comparative effectiveness of robotic versus open radical cystectomy in elderly patients. *J Endourol* 2016;30:212–7.
- [15] Shiloach M, Frencher SK Jr., Steeger JE, Rowell KS, Bartzokis K, Tomeh MG, et al. Toward robust information: data quality and inter-rater reliability in the American College of Surgeons National Surgical Quality Improvement Program. *J Am Coll Surg* 2010;210:6–16.
- [16] Bhalla RG, Wang L, Chang SS, Tyson MD. Association between preoperative albumin levels and length of stay after radical cystectomy. *J Urol* 2017;198:1039–45.
- [17] Cohen J. *Statistical power analysis for the behavioral sciences*. 2nd ed. [S.I.]: [s.n.].
- [18] Novara G, Catto JW, Wilson T, Annerstedt M, Chan K, Murphy DG, et al. Systematic review and cumulative analysis of perioperative outcomes and complications after robot-assisted radical cystectomy. *Eur Urol* 2015;67:376–401.

- [19] Lee R, Ng CK, Shariat SF, Borkina A, Guimento R, Brumit KF, et al. The economics of robotic cystectomy: cost comparison of open versus robotic cystectomy. *BJU Int* 2011;108:1886–92.
- [20] Lee CT, Chang SS, Kamat AM, Amiel G, Beard TL, Fergany A, et al. Alvimopan accelerates gastrointestinal recovery after radical cystectomy: a multicenter randomized placebo-controlled trial. *Eur Urol* 2014;66:265–72.
- [21] Martin AD, Nunez RN, Castle EP. Robot-assisted radical cystectomy versus open radical cystectomy: a complete cost analysis. *Urology* 2011;77:621–5.
- [22] Bennette C, Vickers A. Against quantiles: categorization of continuous variables in epidemiologic research, and its discontents. *BMC Med Res Methodol* 2012;12:21.