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Bladder Cancer

Variations in the Costs of Radical Cystectomy for Bladder Cancer in the USA

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Abstract

Background: Radical cystectomy (RC) for muscle-invasive bladder cancer (BCa) has potential for serious complications, prolonged length of stay and readmissions—all of which may increase costs. Although variations in outcomes are well described, less is known about determinants driving variation in costs.
Objective: To assess surgeon- and hospital-level variations in costs and predictors of high- and low-cost RC.
Design, setting, and participants: Cohort study of 23 173 patients who underwent RC for BCa in 208 hospitals in the USA from 2003 to 2015 in the Premier Healthcare Database.
Outcome measurements and statistical analysis: Ninety-day direct hospital costs; multilevel hierarchical linear models were constructed to evaluate contributions of each variable to costs.
Results and limitations: Mean 90-d direct hospital costs per RC was $39 651 (standard deviation $34 427), of which index hospitalization accounted for 87.8% ($34 803) and postdischarge readmission(s) accounted for 12.2% ($4847). Postoperative complications contributed most to cost variations (84.5%), followed by patient (49.8%; eg, Charlson Comorbidity Index [CCI], 40.5%), surgical (33.2%; eg, year of surgery [25.0%]), and hospital characteristics (8.0%). Patients who suffered minor complications (odds ratio [OR] 2.63, 95% confidence interval [CI]: 2.03–3.40), nonfatal major complications (OR 12.7, 95% CI: 9.63–16.8), and mortality (OR 13.5, 95% CI: 9.35–19.4, all $p < 0.001$) were significantly associated with high costs. As for low-cost surgery, sicker patients (CCI = 2: OR 0.41, 95% CI: 0.29–0.59; CCI = 1: OR 0.58, 95% CI: 0.46–0.75, both $p < 0.001$), those who underwent continent diversion (vs incontinent diversion: OR 0.29, 95% CI: 0.16–0.53, $p < 0.001$), and earlier period of surgery were inversely associated with low costs.
Conclusions: This study provides insight into the determinants of costs for RC. Postoperative morbidity, patient comorbidities, and year of surgery contributed most to observed variations in costs, while other hospital- and surgical-related characteristics such as volume, use of robot assistance, and type of urinary diversion contribute less to outlier costs.
Patient summary: Efforts to address high surgical cost must be tailored to specific determinants of high and low costs for each operation. In contrast to robot-assisted radical prostatectomy where surgeon factors predominate, high costs in radical cystectomy were primarily determined by postoperative complication and patient comorbidities.

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1. Introduction

Bladder cancer (BCa) costs approximately $3 billion in the USA and €4.9 billion in European Union annually [1,2], and incurs the highest lifetime treatment cost per patient among all types of cancers [2,3]. Despite high complication rates, radical cystectomy (RC) remains the gold standard treatment for nonmetastatic muscle-invasive BCa [4]. Recently, there has been a gradual rise in the adoption of robot-assisted RC (RARC), a potentially costlier approach to surgical extirpation of the bladder [5–7]. Given RC's morbidity and substantial economic impact, questions have been raised about variations in care and outcomes. High-volume centers may perform better with process measures and cancer outcomes [8,9] but factors such as postsurgical follow-up vary, with better survival seen in those with excellent postoperative follow-up [10]. Additionally, there are variations in surgical technique, volume, processes of care, and outcomes [11]; it is unknown whether such variations translate into cost differences. A population-based study examining insurance claims found that RC itself accounted for 69% of all charges, while postoperative consultations (7.8%) and complications (6%) accounted for the rest [9], therefore suggesting a possible role of the surgeon to influence costs. Despite the costs of the surgical procedure, a thorough assessment of cost variations and predictors of high costs for RC has not yet been performed. Therefore, we performed a study of costs following RC, hypothesizing that there exists substantial cost variation across surgeons and hospitals. We further hypothesized that the least costly providers would be those with a high annual surgical volume.

2. Patients and methods

2.1. Data source

The Premier Healthcare Database (Premier, Inc., Charlotte, NC, USA) is a nationally representative all-payer database capturing >75 million hospital inpatient discharges. Apart from *International Classification of Diseases, Ninth Revision* (*ICD-9*) and Current Procedural Terminology (CPT) codes, this claims-based database also provides standardized billing items including direct item costs (eg, medications, laboratory services, room and board, etc.). ICD-9 and CPT codes are used to identify patient diagnoses and characteristics of patient encounters (eg, procedures). This database has been featured in prior landmark studies [12,13]. Hospital-specific projection weights are applied to each discharge to project the sample to a national estimate of inpatient discharges. All numbers reported herein refer to the weighted estimates. Given our use of anonymized data, we obtained institutional review board waiver.

2.2. Study population

Using *ICD-9* codes, we identified individuals diagnosed with BCa (188.x, 233.7, 236.7) discharged following RC (57.71) between 2003 and 2015. We excluded those with metastatic disease (196.x, 197.x, 198.x) or other malignancies (140.x–209.79). In our weighted cohort of 53 473 individuals who received RC, we identified 2317 surgeons who performed the surgery in 425 unique hospitals. In our main cohort, we excluded surgeons with annual surgical volume ≤2/yr, which is likely too low to perform a meaningful analysis (median annual surgeon volume 3/yr; 75th percentile: 6; 90th percentile: 11), resulting in a cohort of 23 173 patients operated by 515 unique surgeons at 208 different hospitals in the USA.

2.3. Study variables

Our outcome of interest was direct hospital costs, which included the cost of the entire procedure, inpatient stay, and any inpatient encounters up to 90 d postprocedure. All costs were adjusted to 2016 US dollars using the medical component of the consumer price index.

We examined relevant patient, hospital, and surgeon characteristics. Patient characteristics included age, race, marital status, insurance status, and Charlson Comorbidity Index (CCI). Hospital characteristics included teaching status, urbanicity, size, hospital annual RC volume (low and high defined as >75th percentile; >22/yr), and US geographic region. Surgeon characteristics included annual RC volume (low and high defined as >75th percentile; >10/yr), type of urinary diversion, lymphadenectomy, surgical approach (open vs robot assisted as previously described [14]), and year of surgery (Table 1).

2.4. Statistical analyses

First, we sought to identify the scale of variation in nonadjusted direct hospital costs for all attending surgeons who performed ≥3 RCs/yr. We generated a ranked list of the 515 surgeons ordered by 90-d total direct hospital costs post-RC. To calculate mean costs per surgeon, we divided total direct hospital costs by the number of RCs performed by each surgeon during the study period. This yielded each surgeon's mean direct hospital cost per RC, along with 95% confidence intervals (CIs). We then plotted the distribution of mean direct hospital costs along with 95% CIs for all surgeons from the least costly to the costliest surgeon/hospital. Each data point on the horizontal axis represents an individual attending surgeon/hospital (Fig. 1 and 2).

Second, to assess for the relative contribution of patient-, hospital-, and surgical-level variables, as well as morbidity outcomes on costs, we constructed a multilevel hierarchical linear regression model and calculated the pseudo-R^2 of each variable, which translates to a percentage representing the variability contributed by that variable to 90-d direct hospital costs [15,16].

Finally, we assessed patient-, hospital-, surgical-, and morbidity-related predictors of high- and low-cost RC. Specifically, we determined the dollar thresholds corresponding to the least costly and costliest deciles, which were $18 600 and $68 166 per RC, respectively. We then examined characteristics associated with high- and low-cost RC. Summary statistics were constructed using frequencies and proportions for categorical variables, as well as means and standard deviations (s.d.) for continuous variables. Next, we constructed a multivariable logistic regression model controlling for all aforementioned covariates in order to assess for independent predictors of high- and low-cost surgery. We chose each variable's reference group to be that with the highest frequency. We accounted for clustering by hospitals. There was no significant collinearity across patient, hospital, and surgical covariates used.

2.5. Sensitivity analyses

We performed several sensitivity analyses to determine if our findings were robust and consistent across various study populations. First, we included all surgeons regardless of annual surgeon caseload. Second, we evaluated patients who had prolonged hospital length of stay (pLOS), defined by >75th percentile of 11 d; this was done in order to evaluate if there was still substantial variation in a group of patients whose outcomes were considered “poor.” Third, we evaluated patients who did

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Table 1 – Characteristics of patients in the USA (Premier Healthcare Database) who underwent radical cystectomy from 2003 to 2015, and of those in the lowest and highest 10th percentile of costs per radical cystectomy for bladder cancer

	Low costs (<10th percentile, ie, <$18 600)	High costs (>90th percentile, ie, >$68 166)	Total
	n = 2464	*n* = 2216	*n* = 23 173
Mean costs (s.d.)	$14 007 (5501)	$110 358 (57 549)	$39 651 (34 427)
Patient characteristics			
Age, yr (s.d.)	68.2 (11.8)	70.5 (10.4)	68.6 (12)
Male gender	2075 (84.2%)	1861 (84%)	18 979 (81.9%)
White race	2095 (85%)	1698 (76.6%)	18 352 (79.2%)
Married status	1622 (65.8%)	1229 (55.5%)	14 141 (61%)
Charlson Comorbidity Index			
0	1396 (56.7%)	517 (23.3%)	9937 (42.9%)
1	633 (25.7%)	595 (26.8%)	6654 (28.7%)
≥2	434 (17.6%)	1104 (49.8%)	6581 (28.4%)
Insurance status			
Medicare	1619 (65.7%)	1619 (73.1%)	15 206 (65.6%)
Medicaid	64 (2.6%)	85 (3.8%)	795 (3.4%)
Private insurance	660 (26.8%)	433 (19.5%)	6197 (26.7%)
Other	120 (4.9%)	79 (3.6%)	974 (4.2%)
Hospital characteristics			
Teaching hospital status	961 (39%)	1296 (58.5%)	12 125 (52.3%)
Urban location	2375 (96.4%)	2175 (98.1%)	22 426 (96.8%)
Hospital size			
<300 beds	342 (13.9%)	367 (16.5%)	4895 (21.1%)
300–499 beds	677 (27.5%)	659 (29.8%)	6878 (29.7%)
≥500 beds	1444 (58.6%)	1190 (53.7%)	11 399 (49.2%)
Region			
Midwest	276 (11.2%)	273 (12.3%)	3103 (13.4%)
Northeast	273 (11.1%)	642 (29%)	5056 (21.8%)
South	1621 (65.8%)	954 (43%)	10 619 (45.8%)
West	294 (11.9%)	347 (15.6%)	4394 (19%)
Annual hospital volume >75th percentile (ie, >22/yr)	438 (17.8%)	387 (17.4%)	4087 (17.6%)
Surgical characteristics			
Annual surgeon volume >75th percentile (ie, >10/yr)	525 (21.3%)	345 (15.6%)	4107 (17.7%)
Incontinent urinary diversion	2310 (98%)	2004 (94.1%)	21 144 (94.4%)
Receipt of pelvic lymphadenectomy	1976 (80.2%)	1798 (81.1%)	19 434 (83.9%)
Surgical approach			
Open	2169 (88%)	1763 (79.6%)	18 780 (81%)
Robot assisted	294 (12%)	452 (20.4%)	4392 (19%)
Period of surgery			
2003–2006	556 (22.6%)	651 (29.4%)	6330 (27.3%)
2007–2010	659 (26.7%)	750 (33.8%)	8371 (36.1%)
2011–2015	1248 (50.6%)	815 (36.8%)	8471 (36.6%)

s.d. = standard deviation.

not have pLOS (≤11 d), given that "outliers" would be excluded from a hypothetical alternative payment model with bundled payments. Subgroup analyses with multivariable logistic regression models were performed only if there was clear evidence of significant interaction. Fourth, we evaluated what proportions of costs were related to the index hospitalization versus postdischarge care.

All statistical analyses were performed using STATA 14 (College Station, TX, USA) and SAS 9.3 (SAS Institute, NC, USA). All tests were two sided and $p < 0.05$ was considered statistically significant.

3. Results

Our main cohort consisted of 23 173 RC patients operated by 515 unique surgeons at 208 different hospitals across the USA from 2003 to 2015. Table 1 shows patients' baseline characteristics. Mean 90-d direct hospital costs per RC was $39 651 (s.d. $34 427), of which index hospitalization accounted for 87.8% ($34 803) and postdischarge readmission(s) accounted for 12.2% ($4847; Supplementary Table 1). The lowest decile of costs (<$18 600) consisted of 151 surgeons at 93 hospitals with mean cost for each RC at $14 007 (s.d. $5501), while the top decile of costs (>$68 166) consisted of 222 surgeons in 124 hospitals with mean costs for each RC at $110 358 (s.d. $57,749); this represented a 7.8-fold difference in the mean costs of the least costly and the costliest groups. Mean costs per surgeon/hospital were ranked in an ascending order (Figs. 1 and 2).

Next, we found that postoperative complications heavily influenced cost variations (84.5%). Patient characteristics contributed substantially (49.8%), specifically CCI (40.5%), insurance status (8.5%), and race (4.7%), followed by surgical characteristics (33.2%), which included year of surgery (25.0%), and receipt of pelvic lymphadenectomy (5.3%). Hospital characteristics contributed modestly (8.0%).

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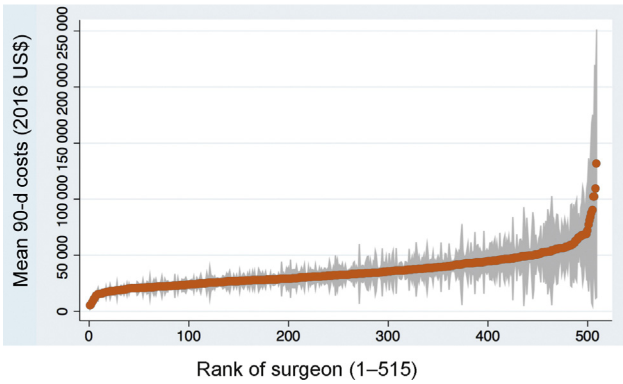

Fig. 1 – Distribution of 515 surgeons in the USA (Premier Healthcare Database), who performed at least 3 radical cystectomies per year, ranked by mean costs per surgery with 95% confidence intervals.

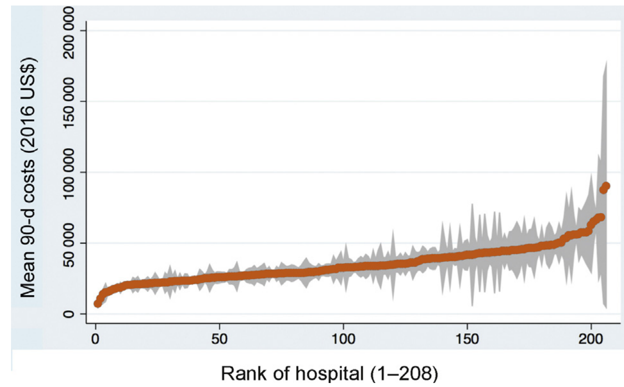

Fig. 2 – Distribution of 208 hospitals in the USA (Premier Healthcare Database), whose surgeons performed at least 3 radical cystectomies per year, ranked by mean cost of surgery with 95% confidence intervals.

Sensitivity analysis of all patients regardless of surgeon volume showed postoperative complications contributing most to costs variations (72.4%), followed by patient (35.4%), surgical (20.2%), and hospital (1.4%) characteristics (Table 2). Among patients with pLOS, similar breakdowns were seen although postoperative complications contributed less (61.3%) compared with other subgroups analyzed.

Multivariable logistic regression models identified several predictors of high-cost (Table 3) and low-cost (Table 3) RC. Significant predictors of high-cost RC include poorer

Table 2 – Contribution of patient, hospital, surgical characteristics, and postoperative complications to variability in costs of radical cystectomy for bladder cancer

	% variability in 90-d direct hospital costs of radical cystectomy			
	Main cohort	Sensitivity analyses		
	Including all surgeons with annual volume ≥3/yr	Including all surgeons regardless of annual volume	Among patients with prolonged LOS (>75th percentile, ie, >11 d)	Among patients without prolonged LOS (≤75th percentile, ie, ≤11 d)
No. of patients included	23 173	53 473	4706	18 466
No. of surgeons involved	515	2317	324	500
No. of hospitals involved	208	425	152	207
Patient characteristics [a]	49.8%	35.4%	45.0%	53.4%
Age	0.3%	0.1%	0.5%	11.5%
Gender	0.1%	0.9%	3.5%	17.1%
Race	4.7%	1.1%	4.1%	1.8%
Marital status	0.4%	1.2%	6.4%	3.6%
Insurance status	8.5%	3.2%	14.6%	16.4%
Charlson Comorbidity Index	40.5%	30.8%	30.3%	37.6%
Hospital characteristics [a]	8.0%	1.4%	2.4%	8.7%
Teaching status	0.3%	0.2%	0.5%	0.3%
Location (urban vs. rural)	0.4%	0.01%	0.0%	0.1%
Hospital size (no. of beds)	0.0%	0.03%	0.1%	0.03%
Geographic region	2.7%	1.0%	0.8%	4.3%
Annual hospital volume	4.2%	0.0%	0.9%	3.7%
Surgical characteristics [a]	33.2%	20.2%	32.3%	34.3%
Annual surgeon volume	2.4%	0.05%	0.5%	0.1%
Type of urinary diversion	4.0%	2.5%	4.4%	4.9%
Pelvic lymphadenectomy	5.3%	1.9%	3.4%	8.9%
Type of surgical approach (open vs robot assisted)	0.1%	0.0%	0.2%	6.7%
Year of surgery	25.0%	16.4%	28.0%	23.4%
Morbidity related				
Type of postoperative complications	84.5%	72.4%	61.3%	65.9%
Total model-calculated % variability in RC costs [a]	88.5%	79.2%	73.1%	79.2%

LOS = length of stay; RC = radical cystectomy.
[a] Each category's contribution of variability in RC costs will not equate to the sum of individual components as this is calculated as a whole from the model. Similarly, the total % variability in RC costs is calculated from the overall adjusted model including all variables and hence will not be equal to the sum of individual variable's contribution to variability in costs.

Table 3 – Multivariable logistic regression for patient, hospital, surgical characteristics, and postoperative complications predicting high-cost (90th percentile) and low-cost (10th percentile) radical cystectomies for bladder cancer

	Main cohort: including all surgeons with annual volume ≥3/yr				Sensitivity analysis: Including all surgeons regardless of annual volume			
	OR	95%	CI	*p* value	OR	95%	CI	*p* value
Predictors of high costs (>90th percentile) for radical cystectomy								
Patient characteristics								
Age (yr)	1.01	1.00	1.03	0.11	0.99	0.98	1.01	0.4
Gender								
Female	Ref.				Ref.			
Male	1.38	0.98	1.94	0.07	1.24	0.98	1.59	0.08
Race								
White	Ref.				Ref.			
Nonwhite	1.14	0.81	1.60	0.87	1.33	1.08	1.62	0.006
Marital status								
Unmarried	1.18	0.92	1.52	0.19	1.15	0.82	1.60	0.4
Married	Ref.				Ref.			
Charlson Comorbidity Index								
0	Ref.				Ref.			
1	1.54	1.08	2.21	0.02	1.16	0.90	1.50	0.25
≥2	2.86	2.04	4.02	<0.001	2.49	1.97	3.15	<0.001
Insurance status								
Medicare	Ref.				Ref.			
Medicaid	1.76	0.93	3.34	0.08	1.46	0.90	2.39	0.13
Private insurance	0.94	0.65	1.34	0.73	0.87	0.67	1.15	0.3
Other	0.87	0.40	1.86	0.71	0.73	0.43	1.26	0.3
Hospital characteristics								
Teaching hospital								
Yes	Ref.				Ref.			
No	0.81	0.53	1.25	0.34	0.75	0.56	0.995	0.046
Location								
Urban	Ref.				Ref.			
Rural	0.70	0.28	1.74	0.44	0.83	0.47	1.45	0.5
Hospital size								
<300 beds	0.79	0.44	1.40	0.41	0.86	0.59	1.26	0.4
300–499 beds	0.94	0.62	1.43	0.76	0.94	0.69	1.28	0.7
≥500 beds	Ref.				Ref.			
Region								
Midwest	0.71	0.40	1.26	0.24	0.74	0.57	0.96	0.03
Northeast	1.24	0.75	2.05	0.40	1.06	0.73	1.53	0.8
South	Ref.				Ref.			
West	0.85	0.50	1.47	0.57	1.15	0.80	1.65	0.4
Annual hospital volume [a]								
≤75th percentile	Ref.				Ref.			
>75th percentile	0.80	0.51	1.25	0.32	0.95	0.70	1.27	0.7
Surgical characteristics								
Annual surgeon volume [b]								
≤75th percentile	Ref.				Ref.			
>75th percentile	0.81	0.54	1.21	0.31	0.75	0.55	1.02	0.07
Type of urinary diversion								
Incontinent	Ref.				Ref.			
Continent	1.56	0.93	2.62	0.09	1.29	0.86	1.94	0.22
Pelvic lymphadenectomy								
No	1.25	0.93	1.69	0.14	1.28	1.04	1.57	0.02
Yes	Ref.				Ref.			
Surgical approach								
Open	Ref.				Ref.			
Robot assisted	1.13	0.73	1.77	0.58	1.41	0.91	2.18	0.13
Year of surgery								
2003–2006	2.93	1.99	4.31	<0.001	3.35	2.58	4.34	<0.001
2007–2010	1.15	0.78	1.68	0.48	1.33	1.06	1.68	0.02
2011–2015	Ref.				Ref.			
Type of complications								
No (Clavien 0)	Ref				Ref.			
Minor (Clavien 1–2)	3.22	2.21	4.69	<0.001	2.63	2.03	3.40	<0.001
Nonfatal major (Clavien 3–4)	15.5	10.5	22.9	<0.001	12.7	9.63	16.8	<0.001
Fatal (Clavien 5)	12.6	6.91	22.9	<0.001	13.5	9.35	19.4	<0.001

Table 3 (*Continued*)

	Main cohort: including all surgeons with annual volume ≥3/yr				Sensitivity analysis: Including all surgeons regardless of annual volume			
	OR	95%	CI	*p* value	OR	95%	CI	*p* value
Predictors of low costs (<10th percentile) for radical cystectomy								
Patient characteristics								
Age (yr)	0.99	0.98	1.01	0.4	1.00	0.99	1.01	0.9
Gender								
Female	Ref.				Ref.			
Male	1.11	0.78	1.58	0.6	1.43	1.13	1.80	<0.001
Race								
White	Ref.				Ref.			
Nonwhite	0.77	0.50	1.17	0.2	0.86	0.57	1.30	0.5
Marital status								
Unmarried	0.80	0.56	1.16	0.2	0.85	0.64	1.12	0.2
Married	Ref.				Ref.			
Charlson Comorbidity Index								
0	Ref.				Ref.			
1	0.58	0.46	0.75	<0.001	0.81	0.68	0.97	0.02
≥2	0.41	0.29	0.59	<0.001	0.47	0.37	0.61	<0.001
Insurance status								
Medicare	Ref.				Ref.			
Medicaid	0.67	0.33	1.36	0.3	0.73	0.45	1.19	0.20
Private insurance	0.86	0.60	1.23	0.4	1.00	0.79	1.28	1.00
Other	1.09	0.52	2.25	0.8	1.06	0.65	1.72	0.8
Hospital characteristics								
Teaching hospital								
Yes	Ref.				Ref.			
No	2.15	0.84	5.48	0.11	1.93	1.01	3.67	0.047
Location								
Urban	Ref.				Ref.			
Rural	1.09	0.48	2.50	0.8	1.08	0.61	1.91	0.8
Hospital size								
<300 beds	0.39	0.16	0.95	0.038	0.63	0.33	1.20	0.2
300–499 beds	0.58	0.27	1.25	0.16	0.83	0.47	1.47	0.5
≥500 beds	Ref.				Ref.			
Region								
Midwest	0.90	0.49	1.65	0.7	0.88	0.51	1.53	0.6
Northeast	0.44	0.14	1.42	0.17	0.58	0.27	1.23	0.15
South	Ref.				Ref.			
West	0.48	0.26	0.91	0.03	0.52	0.29	0.92	0.4
Annual hospital volume [a]								
≤75th percentile	Ref.				Ref.			
>75th percentile	0.91	0.36	2.28	0.8	1.35	0.65	2.78	0.4
Surgical characteristics								
Annual surgeon volume [b]								
≤75th percentile	Ref.				Ref.			
>75th percentile	0.97	0.43	2.19	0.9	1.11	0.64	1.93	0.7
Type of urinary diversion								
Incontinent	Ref.				Ref.			
Continent	0.29	0.16	0.53	<0.001	0.33	0.20	0.55	<0.001
Pelvic lymphadenectomy								
No	1.47	1.04	2.07	0.03	1.38	1.09	1.73	0.007
Yes	Ref				Ref			
Surgical approach								
Open	Ref.				Ref.			
Robot assisted	0.48	0.21	1.09	0.078	0.37	0.18	0.75	0.006
Year of surgery								
2003–2006	0.30	0.17	0.53	<0.001	0.24	0.17	0.35	<0.001
2007–2010	0.38	0.19	0.76	0.01	0.41	0.28	0.60	<0.001
2011–2015	Ref.				Ref.			
Type of complications								
No (Clavien 0)	Ref.				Ref.			
Minor (Clavien 1–2)	0.37	0.27	0.52	<0.001	0.39	0.31	0.48	<0.001
Non-fatal major (Clavien 3–4)	0.13	0.06	0.26	<0.001	0.14	0.08	0.23	<0.001
Fatal (Clavien 5)	0.32	0.09	1.15	0.08	0.44	0.23	0.87	0.02

CI = confidence interval; OR = odds ratio; Ref. = reference.
[a] 75th percentile cutoff for annual hospital volume was ≤/22 and ≤/16 cases/yr for main cohort and sensitivity analysis, respectively.
[b] 75th percentile cutoff for annual surgeon volume was ≤/10 and ≤/6 cases/yr for main cohort and sensitivity analysis, respectively.

health (CCI $\geq$ 2 vs CCI = 0: odds ratio [OR] 2.86, 95% CI: 2.04–4.02, $p < 0.001$) and earlier period of surgery (2003–2006: OR 3.35, 95% CI: 2.58–4.34, $p < 0.001$; 2007–2010: OR 1.33, 95% CI: 1.06–1.68, $p = 0.02$) compared with 2011–2015. Compared with patients without any complications, those who suffered minor complications (OR 2.63, 95% CI: 2.03–3.40), nonfatal major complications (OR 12.7, 95% CI: 9.63–16.8), and mortality (OR 13.5, 95% CI: 9.35–19.4, all $p < 0.001$) were significantly associated with high-costs. Results were largely similar when evaluating surgeons of all volume thresholds.

Sicker patients (CCI = 2: OR 0.41, 95% CI 0.29–0.59; CCI = 1: OR 0.58, 95% CI: 0.46–0.75, both $p < 0.001$), those who underwent continent diversion (vs incontinent: OR 0.29, 95% CI: 0.16–0.53, $p < 0.001$), earlier period of surgery were inversely associated with low-cost RC. Patients who suffered minor complications (OR 0.37, 95% CI: 0.27–0.52), and nonfatal major complications (OR 0.13, 95% CI: 0.06–0.2326, both $p < 0.001$) had decreased odds of low-cost RC (Table 3). Those who did not undergo pelvic lymphadenectomy were significantly associated with low costs (OR 1.74, $p = 0.001$). Sensitivity analysis of surgeons of all volume thresholds showed that robot-assisted surgery was inversely associated with low-cost RC (vs open: OR 0.48, 95% CI: 0.21–0.75, $p = 0.006$).

We did not perform subgroup analyses evaluating the subgroup of patients who did or did not have pLOS as models including the interaction term of pLOS with existing covariates revealed no significant interactions.

4. Discussion

We performed a retrospective analysis of a nationally representative dataset to assess variations in costs for RC and predictors of outlier costs. We observed substantial variation with mean 90-d costs of RC ranging from approximately $14 000 in the least costly decile to over $110 000 in the costliest. This appears to be largely influenced by postoperative complications, followed by patient characteristics (particularly CCI) and surgical characteristics (particularly year of surgery). We found little support in favor of the hypothesis that hospital-level factors drive cost variability for RC (2.4–8.7%); this is in contrast to our finding of significant hospital-driven cost variation for robot-assisted radical prostatectomy (30.4%) [15]. Given the importance of controlling surgical costs, it is vital to assess how patterns of cost variability differ between different operations. In high-morbidity procedures such as RC, initiatives to reduce complications and decrease length of stay may represent high-yield targets for hospitals facing ever-rising financial pressures to reduce costs while improving quality of care [17,18].

Several alternative payment models have been proposed to address high costs. For example, many have proposed bundled payments for surgical care, that is, fixed payments encompassing the expected cost for treatment of a given episode of medical care for a given patient plus a margin for providers [19,20]. Ideally these payments may incentivize hospitals to streamline care delivery and improve coordination. Currently, this payment model is being tested for some surgical procedures [21–24]. Bundled payments are also under consideration for several urological procedures [21]. Providers and hospitals able to control costs may see higher marginal earnings after each operation under bundled payments. In contrast, those with high incremental costs may see losses. The implications are obvious—if money-losing hospitals are predominantly rural, low volume, or low income, then they may shift away from performing certain procedures. It is apparent that postoperative morbidity is significantly associated with high costs, implying that efforts targeted toward decreasing surgical morbidity is one of the key targets for operations such as RC. Of course, this also speaks to a potential unintended consequence of such payment models—if payments are capped then patients with significant comorbidities who are likelier to incur complications and pLOS may in the future be steered toward less aggressive management options for muscle-invasive bladder cancer, thereby potentially missing an opportunity for a truly curative procedure.

Prior studies have demonstrated a morbidity and mortality benefit in centralizing complex surgery (such as RC) to high-volume surgeons at high-volume centers [20,25–27]. Therefore, it is noteworthy that our current study found that neither surgeon or hospital volume was a major contributor to variations in costs, and neither was significantly associated with outlier high or low costs. Although counterintuitive given the widely held belief that increased volume leads to improved efficiency and ultimately lower costs [26], one possibility is that given that we have adjusted for the presence of postoperative complications, any potential association may have already been negated. It may also be the case that the case mix of sicker patients at high-volume hospitals consumes increased resources, which may negate the volume–cost effect [28]. In light of an extensive body of research showing that surgical volume improves outcomes for complex cancer surgery, our results showing an association between complications and high costs probably suggest that centralization will tend to reduce costs for RC.

Our study found that the surgical approach (robot-assisted vs open) was neither a major factor on cost variations (1.4%), nor associated with outlier high costs. On the one hand, this is surprising given that prior studies have shown that robotic surgery incurred higher costs [5,6], even pointing to the higher costs of supplies related to robot-assisted surgery and additional operative time translating to higher operating room costs [7]. It is possible that in highly morbid procedures such as cystectomy that is associated with long hospitalization and frequent complications, other factors tend to predominate over costs of the operation itself. Further, while operating room and supply costs incurred in robot-assisted cystectomy are likely to be still high, these may partially be counteracted by benefits in complications and length of stay [5,7,29]. Reassuringly, RARC utilization was not found to be associated with outlier (>90th percentile) high costs (Table 3).

While prior studies on costs of BCa care have approached the subject only indirectly—through claims data [12,16–18],

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our study provides a national-level assessment using cost data derived directly from hospital accounting. By performing the analysis of direct line-item cost, we were able to reduce the variability due simply to differences in physician fees, or differences related to fixed and indirect costs (which may be unequal between different hospitals); as such, these variations are more likely to represent cost differences secondary to differing patterns and practices of care.

Despite strengths, our study is not devoid of limitations. First, there may be residual differences at the hospital-by-hospital level or even at the surgeon-by-surgeon level in cost estimation, which may contribute to some of the observed variations in costs. Second, there exist unmeasured variables such as case complexity, disease stage/grade, and receipt of chemotherapy, which may impact outcomes and costs. Third, hospital-level negotiations may impact differences in costs. For example, large hospital/physician groups may be able to negotiate cheaper costs for disposables. Fourth, this study was based upon data from the USA and may not be generalizable to other healthcare systems in Europe and other parts of the world. Fifth, our analysis was restricted to encounters within the premier Hospital Network; this implies that in our estimation of surgical volume, we were only able to calculate the number of operations performed within the Premier Hospital Network.

5. Conclusions

This study provides insight into the determinants of costs for RC, identifying substantial surgeon- and hospital-level variations in costs of RC for BCa. Postoperative complications predominantly affect costs, followed by patient comorbidities. Hospital and surgeon characteristics were less influential.

Author contributions: Quoc-Dien Trinh had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Leow, Cole, Chang, Trinh.
Acquisition of data: Chung, Chang.
Analysis and interpretation of data: All authors.
Drafting of the manuscript: Leow, Cole, Trinh.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Leow, Chang.
Obtaining funding: Menon, Choueiri, Chung, Chang, Trinh.
Administrative, technical, or material support: Menon, Kibel, Chang, Trinh.
Supervision: Bellmunt, Menon, Preston, Choueiri, Kibel, Chung, Sun, Chang, Trinh.
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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.eururo.2017.07.016.

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