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Comparative Effectiveness of Surgical Treatments for Prostate Cancer: A Population-Based Analysis of Postoperative Outcomes

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Abstract

Background—Enthusiasm for laparoscopic surgical approaches to prostate cancer treatment has grown, despite limited evidence of improved outcomes compared with open radical prostatectomy. We compared laparoscopic (with or without robotic assistance) versus open radical prostatectomy in terms of postoperative outcomes and subsequent cancer-directed therapy.

Materials and Methods—Using a population-based cancer registry linked with Medicare claims, we identified men age 66 or older with localized prostate cancer who received a radical prostatectomy from 2003-2005. Outcome measures were general medical/surgical complications and mortality within 90 days following surgery; genitourinary/bowel complications within 365 days; receipt of radiation therapy, androgen deprivation therapy or both within 365 days; length of hospital stay.

Results—Of the 5,923 men, 18% received a laparoscopic radical prostatectomy. Adjusting for patient and tumor characteristics, there were no differences in rates of general medical/surgical complications (OR 0.93; 95% CI: 0.77-1.14) or genitourinary/bowel complications (OR 0.96; 95% CI: 0.76-1.22) or in the use of postoperative radiation, androgen deprivation or both (OR 0.80; 95% CI: 0.60-1.08). Laparoscopic prostatectomy was associated with a 35% shorter hospital stay ($p<0.0001$) and a lower rate of bladder neck/urethral obstruction (OR 0.74; 95% CI 0.58-0.94). In laparoscopic patients, surgeon volume was inversely associated with length of hospital stay and the odds of any genitourinary/bowel complication.

Conclusions—Laparoscopic and open radical prostatectomy have similar rates of postoperative morbidity and use of additional treatment. Men considering prostate cancer surgery should understand the expected benefits and risks of each technique to facilitate decision-making and to set realistic expectations.

Keywords

prostate; prostatic neoplasms; prostatectomy; minimally invasive surgical procedures; laparoscopy

Introduction

Approximately 200,000 men in the US will receive a new diagnosis of prostate cancer yearly, and about one-third of these men will receive surgical treatment.¹ Although open retropubic radical prostatectomy (ORP) is the gold standard for definitive resection, laparoscopic radical prostatectomy (LRP) has emerged as an alternative.²⁻⁴ Recently, robotic technology has been introduced to reduce the technical complexity associated with conventional LRP and facilitate adoption of the laparoscopic approach.⁵⁻⁷

Enthusiasm for LRP — and specifically for LRP with robotic assistance — has grown rapidly, despite limited evidence of its superiority to ORP. Only one randomized trial has compared ORP and LRP without robotic assistance, in a sample of 120 procedures performed by a single surgeon.⁸ Most observational studies comparing ORP and LRP have included a small number of patients and surgeons from a single institution.⁹ Two large population-based analyses were limited by a lack of information regarding tumor characteristics.¹⁰⁻¹¹ Our objective was to compare the outcomes of ORP and LRP in a population-based cohort of men with clinically localized prostate cancer, controlling for patient and tumor characteristics, and to examine the impact of surgeon volume in men treated with LRP.

Materials and Methods

Data

We used Surveillance Epidemiology and End Results (SEER) cancer registry data linked with Medicare claims. SEER, sponsored by the National Cancer Institute (NCI), is a consortium of population-based cancer registries in selected geographic areas, covering approximately 25% of the US population.¹² The SEER registries collect data regarding site and extent of disease, first course of therapy, and socio-demographic characteristics, with active follow-up for date and cause of death. Medicare is the primary health insurer for 97%

of Americans 65 years and older, covering inpatient hospital care (Part A), and outpatient care and physician services (Part B). The SEER-Medicare files were used in accordance with a data-use agreement from NCI.

Cohort

We identified prostate cancer patients age 66 years or older who received LRP or ORP in 2003-2005 for a clinically staged T1 or T2 tumor. Men diagnosed only at death, with a prior malignancy, who were enrolled in a managed care plan, or who lacked Part A or B of Medicare were excluded. Surgical procedures were identified by Healthcare Common Procedural Coding System (HCPCS) codes (55866 - LRP; 55840, 55842, 55845 - ORP) in physician claims.

Outcomes

General medical or surgical complications were potentially life-threatening events within 90 days following surgery, including cardiac, vascular, respiratory, wound, and miscellaneous medical/surgical. Genitourinary or bowel complications included bladder neck or urethral obstruction, ureteral complications, incontinence requiring a diagnostic or corrective procedure, fistula or bowel injury, and other genitourinary complications within 365 days following surgery. Receipt of subsequent cancer therapy was defined by a claim for androgen deprivation therapy, radiation therapy or both within 365 days following surgery. Ninety-day mortality was determined from the date of death. Length of hospital stay was identified in the inpatient claim for radical prostatectomy. (Appendix with outcome codes available upon request.)

Covariates

Demographic covariates included patient age, race, geographic location, and marital status. Median income in the census tract of residence was used as a marker of socioeconomic status. Clinical covariates included clinical tumor stage, pathologic stage, number of lymph nodes examined, lymph node involvement, biopsy Gleason score, and diagnosis year. Because SEER did not record exact PSA values until 2004, we used preoperative PSA categorized as elevated, borderline, normal, or unknown. Comorbidity was estimated using the Charlson comorbidity score, based on inpatient claims in the 365 days prior to prostate cancer diagnosis.¹³⁻¹⁴

For each patient, we estimated procedure-specific annual surgeon volume as the number of procedures of the same type (ORP or LRP) performed by the patient's surgeon in the 365 days prior to and including that patient's procedure. For patients treated in 2003, annual surgeon volume was based on the surgeon's procedures during that year.

Statistical Analysis

The impact of procedure type on each outcome was estimated using multivariable regression, controlling for patient and tumor characteristics and surgeon volume. Length of hospital stay was modeled using a log transformation due to its skewed distribution. Generalized estimating equations (GEE) were used to adjust for correlation of outcomes within surgeon. To address potential overfitting, we also built more parsimonious multivariable models, but results were similar and therefore not presented. In LRP patients only, we explored the impact of surgeon volume on outcomes that were associated with surgeon volume in the full cohort. All statistical analyses were performed in SAS version 9.2 (SAS Institute, Cary, NC).

Results

Characteristics of the Cohort

We identified 5,923 men with clinical stage T1 or T2 prostate cancer in the SEER-Medicare dataset who received either LRP or ORP in 2003-2005. Overall, 4,858 men (82%) received ORP and 1,065 men (18%) received LRP (Table 1). In both groups almost 60% of patients were 66 to 69 years of age, 85% were white and about 80% were married. Men who received LRP were more likely to live in a metropolitan area, the West or Northeast and census tracts in the highest quartile of median income. LRP, as a proportion of all procedures, nearly doubled in each successive year.

LRP patients generally had a lower clinical T-stage than ORP patients and, of those with known pathology, a lower pathologic T-stage. The two groups had similar distributions of categorical PSA and Gleason score. In men diagnosed in 2004-2005, ORP patients had a higher preoperative PSA compared with LRP patients and a higher Gleason score. LRP patients were considerably less likely to have any regional lymph nodes examined (57% vs. 80%).

Outcomes

Length of Hospital Stay—Median length of stay was 2.0 days in the LRP group and 3.0 days in the ORP group (Table 2). Controlling for patient and tumor characteristics, length of stay for LRP patients was 35% shorter, on average (Table 3). Length of stay was greater in men who were older, non-white, unmarried, resided in census tracts in the lowest median income quartile, had greater comorbidity, had surgery earlier in the study period, or were operated on by lower-volume surgeons.

Perioperative Mortality, General Medical or Surgical Complications—In both groups, the 90-day mortality rate was < 0.5% (Table 2). A general medical or surgical complication within 90 days postoperatively occurred in 21% of LRP patients and 24% of ORP patients. Adjusted for covariates, the odds of a general medical or surgical complication did not differ significantly between groups (Table 3). These complications were more likely in men who were older, had greater comorbidity or whose surgeons had lower procedure-specific volume.

Genitourinary or Bowel Complications—In the first year following surgery, almost 40% of LRP patients had a genitourinary or bowel complication, compared with 35% of ORP patients (Table 2). Controlling for patient and tumor characteristics, procedure type was not significantly associated with the odds of a genitourinary or bowel complication (Table 4). Only surgeon volume, marital status, and clinical stage were significant predictors of this outcome.

In both groups, about 29% of men had a bladder neck or urethral obstruction (Table 2). Controlling for patient and tumor characteristics, LRP was associated with lower odds of this complication (OR 0.74, 95% CI 0.58–0.94) (Table 4), which was more common in men who were unmarried, lived in the Northeast, had a clinically staged T2 tumor, or did not have a pelvic lymphadenectomy. Surgeon volume was inversely associated with bladder neck or urethral obstruction.

Subsequent Cancer Therapy—About 9% of LRP patients and 12% of ORP patients received radiation therapy, androgen deprivation therapy or both in the year following surgery (Table 2). Adjusted for patient and tumor characteristics, procedure type was not significantly associated with receipt of subsequent cancer therapy (Table 3). When we

limited the endpoint to subsequent cancer therapy in postoperative days 120 through 365, results were similar.

Surgeon Volume in LRP—Among LRP patients, annual procedure-specific surgeon volume varied from 1 to 68. More than half of these men had a LRP performed by a surgeon whose annual volume was less than 5 (Figure 1). Fewer than 20% of LRP patients had a surgeon whose annual volume was 30 or more.

Controlling for patient and tumor characteristics, surgeon volume was associated with a shorter length of stay ($p<0.001$, Figure 2A), but not with general medical or surgical complications ($p=0.33$, Figure 2B) in the LRP group. The inverse relationship between surgeon volume and both genitourinary or bowel complications ($p<0.01$, Figure 2C) and bladder neck or urethral obstruction ($p<0.05$, Figure 2D) persisted in the LRP group. The predicted probability of a bladder neck or urethral obstruction after LRP was 31% for the average patient whose surgeon performed 5 LRPs in the preceding year and decreased to 16% for the average patient whose surgeon performed 30 LRPs. Results were similar when we relaxed the assumption of linearity between surgeon volume and each outcome.

Discussion

Since its introduction, the use of robotic radical prostatectomy has increased exponentially, despite a lack of high-quality evidence demonstrating superiority to ORP.⁵⁻⁶ In the large population-based dataset analyzed here, we found no difference between procedures in 90-day mortality, 90-day general medical or surgical complications, or use of additional cancer therapy in the year following surgery. Although we observed some differences in unadjusted rates of complications and subsequent cancer therapy, these differences were not statistically significant when we controlled for patient and tumor characteristics and surgeon volume. Differences in length of stay and bladder neck or urethral obstruction persisted in multivariable analysis, both favoring LRP.

Our findings of similar 90-day general complication rates and rates of any genitourinary or bowel complication at one year are consistent with several single-institution reports, and suggest that procedure type has little, if any, impact on morbidity.^{9, 15-16} Patient age, comorbidity, and surgeon volume were the only significant predictors of general medical or surgical complications, while surgeon volume, marital status, and clinical stage were the only significant predictors of any genitourinary or bowel complication.

Some of our results conflict with other recent population-based studies. In a nationwide sample of Medicare beneficiaries, Hu et al. found a lower risk of postoperative complications, but a greater likelihood of additional cancer treatment in LRP patients.¹¹ In the absence of information about disease characteristics, the investigators were able to control only for age, race, comorbidity, and geographic region. We found that controlling for both patient and tumor characteristics, including clinical or pathologic stage, lymph node examination and involvement, preoperative PSA, and preoperative Gleason score, had a substantial impact on our conclusions. This likely reflects confounding, particularly by higher-risk tumor characteristics which were more common in the ORP group.

Our findings with respect to bladder neck or urethral obstruction are consistent with those reported by Hu et al. in a separate claims-based analysis.¹⁰ In that cohort, which included men of all ages, LRP patients had lower odds of bladder neck or urethral obstruction. However, in their analysis of Medicare beneficiaries, Hu et al. reached the opposite conclusion, finding a greater risk of bladder neck or urethral obstruction in men who received LRP.¹¹ Although bladder neck and urethral obstructions requiring operative

intervention were uncommon even in our ORP group, these complications can lead to chronic urinary problems, impairing function and quality of life and requiring multiple corrective procedures.¹⁷

Comparisons of LRP and ORP have consistently found reduced blood loss and shorter length of hospital stay with LRP.⁹ We were not able to assess the former, but our results corroborate the latter. While reduced length of stay is commonly stated as an advantage of LRP, it is not clear that it yields the economic advantages its advocates promote. Cost comparisons of the two procedures suggest that savings in hospital room and board costs with LRP do not necessarily offset the increased operative costs associated with use of the robot, particularly in low-volume settings.¹⁸⁻¹⁹ Standardization of care pathways may reduce differences between the two procedures in length of stay.²⁰⁻²¹

The rapid uptake of LRP has important implications for providers and patients.²² Hospital marketing of robotic prostatectomy is widespread, and is not regulated by the Food and Drug Administration rules that govern direct-to-consumer advertising by device manufacturers. In a simple Internet search of hospital websites, we found that many promoted the robotic procedure with claims that overstated its potential benefits or implied a level of certainty that is not currently supported by existing evidence. It is therefore not surprising that in a survey of 400 men who had ORP or robot-assisted LRP, those who had the robotic procedure were more than 3 times as likely to express regret with their treatment choice, while men who had ORP were more than 4 times as likely to express satisfaction.²³

Increased use of the robotic approach also means that the procedure is being adopted by less experienced surgeons. We found that annual surgeon volume was associated with a shorter hospital stay, lower risk of general medical or surgical complications, genitourinary or bowel complications, and specifically bladder neck or urethral obstruction. In LRP patients only, surgeon volume was predictive of most of these endpoints, but not of general medical or surgical complications. While our measure of annual surgeon volume included only procedures performed on men age 66 or older in the SEER-Medicare dataset, it should be highly correlated with the volume of procedures performed on men of all ages.²⁴ Efforts to regionalize robotic prostatectomy may yield both clinical and economic benefits.

Based on the large, population-based linked SEER-Medicare dataset, our findings are generalizable to surgical prostate cancer patients age 66 and older, and we were able to control for important patient and tumor. However, there may have been residual confounding by unmeasured factors. Misclassification of outcomes is another possible limitation; our methods favored inclusion of all potentially relevant billing codes to identify complications. Similarly, because all LRPs shared a single HCPCS code (55866), it was impossible to distinguish procedures performed with and without robotic assistance. We estimate that most LRPs were performed with robotic assistance, based on information provided by the sole manufacturer of the robotic system. Finally, we could not distinguish with certainty between adjuvant and salvage therapies. Therefore, receipt of subsequent cancer therapy is not an ideal measure of short-term cancer control.

While we evaluated important outcomes of prostate cancer surgery, there are numerous other endpoints we could not analyze. Long-term oncologic control, urinary and erectile function, quality of life and costs are pertinent to both patients and providers. We hope that recent enthusiasm and funding for comparative effectiveness studies prompts further comparisons of the different approaches to radical prostatectomy, and address these important endpoints in prospective clinical studies.²⁵

Conclusion

Our results suggest that ORP and LRP have similar rates of postoperative mortality and morbidity. Controlling for important patient and tumor characteristics, the only differences favoring LRP were a shorter length of stay and a lower risk of bladder neck or urethral obstruction. All men considering radical prostatectomy should be clearly informed about the differences between the two techniques as well as the similarities in their expected outcomes and make treatment decisions in collaboration with an experienced surgeon.

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Abbreviations

AJCC	American Joint Committee on Cancer Staging Manual, 6th Edition
CMS	Centers for Medicare and Medicaid Services
GEE	Generalized Estimating Equations
HCPCS	Healthcare Common Procedural Coding System
ICD-9	International Classification of Diseases codes, 9th Edition
LRP	Laparoscopic Radical Prostatectomy
NCI	National Cancer Institute
PSA	Prostate-Specific Antigen
ORP	Open Radical Prostatectomy
SEER	Surveillance Epidemiology and End Results

Figure 1.

Cumulative Distribution of Annual Procedure-Specific Surgeon Volume in Laparoscopic Radical Prostatectomy (With or Without Robotic Assistance) Patients

For each patient, we estimated procedure-specific annual Medicare surgeon volume as the number of procedures of the same type (ORP or LRP) performed by the patient's surgeon in the 365 days prior to that patient's procedure, including the patient's surgery.

Figure 2A

Figure 2B

Figure 2C

Figure 2D

Figure 2 (A - D).

Relationship of Annual Procedure-Specific Surgeon Volume in SEER-Medicare with Postoperative Outcomes

For LRP (with or without robotic assistance) patients, plots are derived from multivariable linear regression models adjusted for patient and tumor characteristics and corrected for within-surgeon correlation. A, predicted length of stay (LOS, days); B, predicted risk of general medical or surgical complication within 90 days of surgery; C, predicted risk of any genitourinary or bowel complication within 365 days of surgery; D, predicted risk of bladder neck or urethral obstruction within 365 days of surgery. Blue dots represent individual predicted outcomes. The linear relationship between each outcome (solid line) and 95% confidence intervals around the mean predicted values (dashed lines) are shown.

Table 1

Characteristics of cohort by procedure type

Characteristic	All No. Pts (%)	ORP No. (Col %)	LRP No. (Col %)	<i>p</i> ^a
N	5,923	4,858	1,065	
Age Category				
66-69	3,461 (58)	2,848 (59)	613 (58)	0.94
70-74	2,040 (34)	1,666 (34)	374 (35)	
75-59	390 (7)	318 (7)	(<8)	
80+	32 (<1)	26 (<1)	(<1)	
Race				
White	5,038 (85)	4,132 (85)	906 (85)	<0.01
Black	430 (7)	371 (8)	59 (6)	
Other	453 (8)	354 (7)	99 (9)	
Married				
Yes	4,779 (81)	3,929 (81)	850 (80)	0.19
No	860 (15)	723 (15)	137 (13)	
Unknown	284 (5)	206 (4)	78 (7)	
Census tract median income				
Q1	1,475 (25)	1,318 (27)	157 (15)	<0.0001
Q2	1,477 (25)	1,241 (26)	236 (22)	
Q3	1,478 (25)	1,203 (25)	275 (26)	
Q4	1,476 (25)	1,083 (22)	393 (37)	
Urban residence				
Metro	5,136 (87)	4,143 (85)	993 (93)	<0.0001
Non-Metro	786 (13)	714 (15)	72 (7)	
Geographic area				
Northeast	640 (11)	504 (10)	136 (13)	<0.0001
South	810 (14)	719 (15)	91 (9)	
Midwest	685 (12)	570 (12)	115 (11)	
West	3,788 (64)	3,065 (63)	723 (68)	
Year of surgery				
2003	1,979 (33)	1,830 (38)	149 (14)	<0.0001
2004	2,054 (35)	1,688 (35)	366 (34)	
2005	1,890 (32)	1,340 (28)	550 (52)	
Charlson comorbidity score				
0	4,689 (79)	3,826 (79)	863 (81)	0.22
1	958 (16)	798 (16)	160 (15)	
2+	276 (5)	234 (5)	42 (4)	
Clinical stage				
T1	2,692 (45)	2,112 (43)	580 (54)	<0.0001

Characteristic	All No. Pts (%)	ORP No. (Col %)	LRP No. (Col %)	<i>p</i> ^a
T2	3,231 (55)	2,746 (57)	485 (46)	
Pathologic stage				
T0/Tis	13 (<1)	(<1)	(<1)	0.01
T2	4,266 (72)	3,496 (72)	770 (72)	
T3	1,142 (19)	977 (20)	165 (15)	
T4	72 (1)	(<2)	(<2)	
Unknown	430 (7)	313 (6)	117 (11)	
PSA				
Elevated	4,586 (77)	3,760 (77)	826 (78)	0.38
Borderline	381 (6)	312 (6)	69 (6)	
Normal	409 (7)	324 (7)	85 (8)	
Unknown	547 (9)	462 (10)	85 (8)	
Gleason Score				
2-4	62 (1)	52 (1)	10 (1)	0.81
5-6	3,018 (51)	2,483 (51)	535 (50)	
7+	2,805 (47)	2,293 (47)	512 (48)	
Lymph nodes examined				
0	1,580 (27)	969 (20)	611 (57)	<0.0001
>0	4,328 (73)	3,878 (80)	450 (42)	
Lymph node involvement				
No ^c	5,735 (97)	4,708 (97)	1,027 (96)	<0.01
Yes	106 (2)	99 (2)	(<1)	
Unknown	82 (1)	51 (1)	(<4)	
PSA laboratory value (n=3,073)				
< 4	362 (12)	263 (11)	99 (14)	<0.01
4 - 10	2,121 (69)	1,602 (68)	519 (71)	
>10 - ≤ 20	429 (14)	342 (15)	87 (12)	
> 20	161 (5)	137 (6)	24 (3)	
Gleason score (n=3,480)				
2 - 5	(<3)	(<3)	(<1)	<0.01
6	1,281 (37)	960 (36)	321 (40)	
7	1,681 (48)	1,279 (48)	402 (50)	
8	260 (7)	208 (8)	52 (6)	
9	163 (5)	138 (5)	25 (3)	
10	(<1)	(<1)	(<1)	

Abbreviations: ORP, open radical prostatectomy; LRP, laparoscopic radical prostatectomy (with or without robotic assistance); Q1, lowest quartile; Q4, highest quartile; PSA, prostate-specific antigen.

Unknown values and other cell counts where N<11 not shown as per SEER-Medicare Data Use Agreement.

^aChi-square test; Unknowns excluded.

^b PSA laboratory values and exact Gleason score in SEER for cases diagnosed during 2004-2005.

^c Includes men who did not undergo a pelvic lymph node dissection.

Table 2

Frequency of postoperative outcomes by procedure type

Outcome	ORP N=4,858	LRP N=1,065
Length of hospital stay, days		
N	4,697	1,006
Median (Interquartile range)	3.0 (2.0-4.0)	2.0 (1.0-2.0)
Mortality from any cause, within 90 days (%)	<0.5	<0.5
General medical or surgical complications, within 90 days (%)		
Any	1172 (24.1)	228 (21.4)
Cardiac	180 (3.7)	32 (3.0)
Respiratory	423 (8.7)	71 (6.7)
Vascular	198 (4.1)	35 (3.3)
Wound	133 (2.7)	26 (2.4)
Miscellaneous medical/surgical	635 (13.1)	127 (11.9)
Genitourinary or Bowel complications, within 365 days (%)		
Any	1722 (35.4)	429 (40.3)
Bladder neck/urethral obstruction	1422 (29.3)	306 (28.7)
Ureteral stricture	164 (3.4)	36 (3.4)
Incontinence requiring procedure	245 (5.0)	66 (6.2)
Fistula/bowel injury	115 (2.4)	41 (3.8)
Other genitourinary	205 (4.2)	107 (10.0)
Subsequent cancer therapy, within 365 days (%)		
Any	563 (11.6)	98 (9.2)
Radiation only	394 (8.1)	68 (6.4)
Androgen deprivation only	330 (6.8)	58 (5.4)
Radiation and androgen deprivation	161 (3.3)	28 (2.6)

Abbreviations: ORP, open radical prostatectomy; LRP, laparoscopic radical prostatectomy (with or without robotic assistance).

Impact of procedure type, patient and tumor characteristics on general perioperative complications, length of hospital stay, and subsequent cancer therapy

Table 3

	General Medical or Surgical Complication ^d		Length of Hospital Stay ^b		Subsequent Cancer Therapy ^c	
	OR (95% CI)	p	Estimate ^d (95% CI)	p	OR (95% CI)	p
Procedure type						
ORP	REF	0.49	REF	<0.0001	REF	0.14
LRP	0.93 (0.77, 1.14)		0.65 (0.61, 0.70)		0.80 (0.60, 1.08)	
Surgeon volume ^e	0.991 (0.982, 0.999)	<0.05	0.992 (0.990, 0.994)	<0.0001	1.01 (0.99, 1.02)	0.43
Age						
66-69	REF	<0.0001	REF	<0.0001	REF	0.25
70-74	1.20 (1.05, 1.38)		1.04 (1.01, 1.06)		1.14 (0.95, 1.37)	
75+	1.95 (1.55, 2.44)		1.10 (1.05, 1.15)		1.21 (0.89, 1.65)	
Race						
White	REF	0.19	REF	0.001	REF	0.20
Black	1.19 (0.93, 1.52)		1.06 (1.01, 1.11)		1.09 (0.76, 1.57)	
Other	1.15 (0.93, 1.42)		1.06 (1.02, 1.11)		1.33 (0.97, 1.83)	
Median income						
Q1	REF	0.44	REF	<0.001	REF	0.58
Q2	0.90 (0.75, 1.08)		0.98 (0.94, 1.01)		0.92 (0.71, 1.20)	
Q3	0.85 (0.70, 1.04)		0.95 (0.92, 0.98)		1.03 (0.79, 1.34)	
Q4	0.90 (0.74, 1.09)		0.94 (0.91, 0.97)		1.10 (0.85, 1.43)	
Urban residence						
Metro	REF	0.26	REF	0.32	REF	0.41
Non-Metro	1.12 (0.92, 1.37)		1.02 (0.98, 1.06)		0.88 (0.65, 1.20)	
Region						
Northeast	REF	0.07	REF	0.73	REF	0.19
South	1.02 (0.77, 1.35)		1.00 (0.93, 1.07)		1.21 (0.77, 1.91)	
Midwest	0.75 (0.57, 0.99)		1.03 (0.95, 1.11)		1.50 (0.96, 2.33)	
West	0.93 (0.74, 1.17)		1.02 (0.96, 1.09)		1.12 (0.76, 1.65)	

	General Medical or Surgical Complication ^a		Length of Hospital Stay ^b		Subsequent Cancer Therapy ^c	
	OR (95% CI)	P	Estimate ^d (95% CI)	P	OR (95% CI)	P
Married						
Yes	REF	0.39	REF	<0.0001	REF	<0.05
No	0.92 (0.77, 1.09)		1.06 (1.03, 1.10)		0.88 (0.68, 1.13)	
Unknown	1.13 (0.87, 1.48)		0.95 (0.91, 1.00)		0.40 (0.21, 0.76)	
Clinical stage						
T1	REF	0.26	REF	0.88	REF	<0.001
T2	1.07 (0.95, 1.21)		1.00 (0.98, 1.02)		1.40 (1.18, 1.67)	
PSA						
Normal	REF	0.63	REF	0.64	REF	<0.05
Borderline	0.81 (0.57, 1.15)		1.00 (0.94, 1.07)		2.03 (1.17, 3.51)	
Elevated	0.93 (0.72, 1.21)		0.99 (0.95, 1.04)		2.02 (1.28, 3.19)	
Unknown	0.98 (0.71, 1.35)		1.02 (0.97, 1.08)		1.58 (0.91, 2.72)	
Lymph nodes involved ^f						
No	REF				REF	<0.0001
Yes					11.73 (7.77, 17.69)	
Lymph nodes examined						
None	REF	0.31	REF	0.15	REF	
Any	1.08 (0.93, 1.26)		1.02 (0.99, 1.05)		1.01 (0.79, 1.28)	0.97
Gleason						
2-4	1.65 (0.94, 2.91)	0.18	1.05 (0.95, 1.15)	0.38	1.23 (0.36, 4.20)	<0.0001
5-6	REF		REF		REF	
7+	0.98 (0.86, 1.11)		0.99 (0.97, 1.01)		3.13 (2.56, 3.83)	
Comorbidity						
0	REF	<0.0001	REF	<0.0001	REF	<0.05
1	1.34 (1.13, 1.58)		1.03 (1.00, 1.06)		1.04 (0.82, 1.31)	
2+	3.35 (2.62, 4.27)		1.13 (1.07, 1.19)		0.52 (0.32, 0.86)	
Year of surgery						
2003	REF	0.29	REF	<0.01	REF	0.10

	General Medical or Surgical Complication ^a		Length of Hospital Stay ^b		Subsequent Cancer Therapy ^c	
	OR (95% CI)	p	Estimate ^d (95% CI)	p	OR (95% CI)	p
2004	1.10 (0.95, 1.27)		0.98 (0.96, 1.00)		0.79 (0.63, 0.98)	
2005	1.13 (0.96, 1.34)		0.95 (0.92, 0.98)		0.85 (0.68, 1.06)	

Abbreviations: ORP, open radical prostatectomy; LPR, laparoscopic radical prostatectomy (with or without robotic assistance); OR, odds ratio; CI, confidence interval; REF, reference; Q1, lowest quartile; Q4, highest quartile; PSA, prostate-specific antigen.

^aWithin 90 days following surgery
^bFor initial surgical hospitalization

^cRadiation or androgen deprivation therapy or both administered within 365 days following surgery

^dEstimate denotes change in the ratio of expected mean length of stay for covariate vs. reference value

^eOR interpretable as the decrease in odds of the outcome for every additional procedure performed by a patient's surgeon in the 365 days prior to his own surgery; length of stay estimate interpretable as the percentage change in average length of hospital stay for every additional procedure performed by a patient's surgeon in the year prior to their own surgery

^fOnly considered clinically relevant for subsequent cancer therapy outcome, therefore not included in other models

Table 4

Impact of procedure type, patient and tumor characteristics on postoperative genitourinary or bowel complications within 1 year following surgery

	Any Genitourinary or Bowel Complication		Bladder Neck or Urethral Obstruction	
	OR (95% CI)	P	OR (95% CI)	P
Procedure type				
ORP	REF	0.74	REF	<0.05
LRP	0.96 (0.76, 1.22)		0.74 (0.58, 0.94)	
Surgeon volume ^a	0.98 (0.97, 0.99)	<0.001	0.98 (0.97, 0.99)	<0.01
Age				
66-69	REF	0.80	REF	0.97
70-74	1.03 (0.91, 1.16)		1.01 (0.90, 1.15)	
75+	1.07 (0.86, 1.32)		1.01 (0.80, 1.28)	
Race				
White	REF	0.90	REF	0.50
Black	0.95 (0.77, 1.18)		1.02 (0.81, 1.28)	
Other	0.99 (0.78, 1.24)		0.87 (0.69, 1.10)	
Median income				
Q1	REF	0.23	REF	0.37
Q2	0.97 (0.83, 1.13)		1.05 (0.89, 1.23)	
Q3	0.85 (0.71, 1.00)		0.91 (0.76, 1.10)	
Q4	0.89 (0.74, 1.08)		0.92 (0.76, 1.12)	
Urban residence				
Metro	REF	0.54	REF	0.55
Non-Metro	1.07 (0.87, 1.30)		1.06 (0.87, 1.31)	
Region				
Northeast	REF	0.07	REF	<0.01
South	0.68 (0.51, 0.91)		0.61 (0.44, 0.82)	
Midwest	0.80 (0.59, 1.09)		0.81 (0.59, 1.12)	
West	0.83 (0.66, 1.04)		0.87 (0.68, 1.12)	
Married				
Yes	REF	<0.01	REF	<0.01
No	1.29 (1.11, 1.49)		1.28 (1.09, 1.50)	
Unknown	0.91 (0.69, 1.20)		0.89 (0.66, 1.19)	
Clinical stage				
T1	REF	<0.01	REF	<0.05
T2	1.18 (1.06, 1.33)		1.14 (1.01, 1.28)	
PSA				
Normal	REF	0.21	REF	0.29
Borderline	0.81 (0.59, 1.11)		0.77 (0.57, 1.04)	

	Any Genitourinary or Bowel Complication		Bladder Neck or Urethral Obstruction	
	OR (95% CI)	p	OR (95% CI)	P
Elevated	0.97 (0.77, 1.23)		0.95 (0.78, 1.17)	
Unknown	1.10 (0.83, 1.45)		1.00 (0.75, 1.32)	
Lymph node examination				
None	REF	0.09	REF	<0.05
Any	0.89 (0.77, 1.02)		0.86 (0.74, 1.00)	
Gleason				
2-4	1.63 (0.98, 2.69)	0.17	1.45 (0.88, 2.39)	0.30
5-6	REF		REF	
7+	1.02 (0.91, 1.14)		0.98 (0.87, 1.10)	
Comorbidity				
0	REF	0.20	REF	0.26
1	1.08 (0.94, 1.25)		1.12 (0.96, 1.31)	
2+	1.21 (0.95, 1.55)		1.14 (0.87, 1.49)	
Year of surgery				
2003	REF	0.68	REF	0.82
2004	1.05 (0.91, 1.21)		1.02 (0.88, 1.19)	
2005	1.06 (0.92, 1.23)		1.05 (0.90, 1.22)	

Abbreviations: ORP, open radical prostatectomy; LPR, laparoscopic radical prostatectomy (with or without robotic assistance); OR, odds ratio; CI, confidence interval; REF, reference; Q1, lowest quartile; Q4, highest quartile; PSA, prostate-specific antigen.

^a OR interpretable as the decrease in odds of the outcome for every additional procedure performed by a patient's surgeon in the 365 days prior to his own surgery