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Regional Cost Variations of Robot-Assisted Radical Prostatectomy Compared With Open Radical Prostatectomy

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Abstract

Robot-assisted radical prostatectomy (RARP) has been shown to be as effective as open radical prostatectomy (ORP), however at a higher cost. In this study we used a nationally representative database to evaluate regional cost variation in the United States for patients who undergo RARP versus ORP and found that in the Northeast region, ORP is more costly than RARP.

Introduction—The purpose of the study was to evaluate the cost differences between robot-assisted radical prostatectomy (RARP) and open radical prostatectomy (ORP) in various census regions of the United States because RARP has been reported to be more expensive than ORP with significant regional cost variations in radical prostatectomy (RP) cost across the United States.

Patients and Methods—International Classification of Diseases, Ninth Revision, Clinical Modification codes were used to identify patients with prostate cancer who underwent RARP or ORP from the Nationwide Inpatient Sample (NIS) database from 2009 to 2011. Hospital costs were compared using the Wilcoxon rank sum test and multivariable linear regression analysis adjusting for age, sex, race, comorbidities, and hospital characteristics.

Results—From the NIS database, 24,636 RARP and 13,590 ORP procedures were identified and evaluated. The lowest cost overall was in the South; the highest cost RARP was in the West and for ORP in the Northeast. In multivariable analysis, adjusted according to patient and hospital characteristics, RARP was 43.3% more costly in the Midwest, 37.2% more costly in the South, and 39.1% more costly in the West ($P < .0001$ for all). In contrast, the cost for RARP in the Northeast was 12.8% less than for ORP ($P < .0001$).

Conclusion—Cost for RP significantly varies within the nation and in most regions it is significantly greater for RARP than for ORP. ORP in the Northeast is more costly than RARP. Further research is needed to delineate the reason for these differences and to optimize the cost of RP.

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Disclosure
The authors have stated that they have no conflicts of interest.

Keywords

Cost; Nationwide inpatient sample; Open prostatectomy; Regional variation; Robotic radical prostatectomy

Introduction

Prostate cancer (PCa) in the United States will be responsible for an estimated 233,000 new diagnoses and 29,480 deaths in 2014.[1] Although open radical prostatectomy (ORP) has long been the mainstay of treatment for localized PCa, the advent of the da Vinci robotic system (Intuitive Surgical, Sunnyvale, CA) has led to rapid and widespread adoption of robot-assisted radical prostatectomy (RARP). Most radical prostatectomy (RP) procedures are now performed with robotic assistance, with recent estimates as high as 85%.[2] This widespread adoption has occurred despite the lack of high-quality evidence of superiority of RARP over ORP. The only benefits of RARP that have been shown consistently are shorter length of stay, decreased blood loss, and lower rates of transfusion. More recently, a minimally invasive approach has been shown to have a lower positive surgical margin rate, although functional and long-term oncologic outcomes remain essentially equal between RARP and ORP.[3–5]

A common criticism of RARP is its significantly higher cost compared with ORP. Studies have shown RARP to be from $200 to $2000 more expensive than ORP.[6,7] Many factors contribute to the high overall cost of RARP including the initial capital expenditure of purchasing the robotic system, maintenance cost, disposable equipment, and longer operating room time.[8–10] With the increased focus on controlling health care expenditures, the costs of PCa care has been scrutinized and there is a need for better understanding of the elements of RARP that drive this high cost. A previously published population-based study has identified regional variation as a significant contributor to the variance in RP cost in the United States.[11] In the present study we used contemporary data and focused primarily on evaluation of total hospital costs for RP overall and separately for RARP and ORP and their comparison between different US census regions to identify possible discrepancies and underlying contributors to cost across the country.

Patients and Methods

Data Source

After obtaining the institutional review board approval of the Rutgers University (IRB# 2014004118), we examined the Nationwide Inpatient Sample (NIS) database for the years 2009 to 2011. The NIS is the largest US publicly available all-payer database containing information on approximately 20% of all hospital stays in the US community hospitals, which translates to an average of 8 million observations annually. Detailed information about NIS is available at http://www.hcupus.ahrq.gov/db/nation/nis/nisdbdocumentation.jsp.

Study Population

All men of age 18 years of age and older who were admitted to acute care hospitals with a principal diagnosis of PCa (International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM] diagnosis code 185) and underwent RP (ICD-9-CM procedure code 60.5 for principal procedure) were evaluated initially. Among them, patients who underwent RARP (ICD-9-CM procedure code 17.42 in any procedure position) or ORP were selected. To identify the ORP group, we excluded from the initial cohort those with codes for RARP, other robotic-assisted procedures (ICD-9-CM codes 17.41, 17.43–17.49), or laparoscopy (ICD-9-CM procedure code 54.21).

Outcome Measurements and Statistical Analysis

The primary outcome measure was the total hospital cost of RP for PCa and its variation depending on the type of surgical procedure (RARP or ORP) and selected patient and hospital characteristics. Patient characteristics included age, race, comorbidities, and postoperative complications. We included in the analysis the following Agency for Healthcare Research and Quality comorbidity measures that are available in the NIS: congestive heart failure, hypertension, chronic pulmonary disease, pulmonary circulation disease, diabetes with and without chronic complications, renal failure, and obesity. To identify postoperative complications, the following ICD-9-CM diagnosis codes for secondary diagnoses were used: 997.1, 410.00–410.02, 410.10–410.12, 410.20–410.22, 410.30–410.32, 410.40–410.42, 410.50–410.52, 410.60–410.62, 410.70–410.72, 410.80–410.82, 410.90–410.92, and 427.5 for cardiac complications including myocardial infarction; 997.3x, 480.x, 481, 482.0–482.2, 482.3x, 482.4x, 482.8x, 482.9, 483.x, 484.x, 485, 486, 507.0, 512.1, 518.4, 518.5, 518.81, and 518.82 for respiratory complications and pneumonia; 997.5, 584.x, and 593.81 for renal complications and acute renal failure; 997.02, 430, 431, and 432.x for postoperative stroke and cerebral hemorrhage; 038.0, 038.1x, 038.2, 038.3, 038.4x, 038.8, 038.9, 995.91, 995.92, 998.0, 785.52, 996.61, 996.62, and 999.3x for sepsis and bloodstream infection; 998.5x, 998.30–998.32, and 998.83 for surgical site infection; 008.45 for *Clostridium difficile* pseudomembranous colitis; 567.1, 567.2x, and 567.3x for peritonitis; 599.0 for urinary tract infection; 996.64 for infection due to indwelling urinary catheter; 285.1 and 998.11–998.12 for bleeding; 286.6 for disseminated intravascular coagulation; 415.1x for pulmonary embolism; 444.22 for embolism or thrombosis of lower extremity arteries; and 453.4x for venous embolism and thrombosis of deep vessels of the lower extremity. In addition to the hospital characteristics in the NIS (region, location, size according to number of beds, control/ownership, teaching status) we designated hospitals with ≥ 33 prostatectomies per year as “high-volume” and those with < 33 procedures per year as “low-volume” hospitals.[12]

Data analysis and all statistics were performed using SAS software (SAS Institute, Cary, NC), version 9.4. We used the Healthcare Cost and Utilization Project Cost-to-Charge Ratio files to convert hospital charges into actual costs that were tested for normality, which represented the total hospital cost. Because costs were not normally distributed and skewed to the right, we presented cost as median with interquartile range and analyzed cost difference between groups using the nonparametric Wilcoxon rank-sum test. All cost data were adjusted for inflation to 2011 dollars. To minimize the effect of the various potential confounders on hospital costs in comparisons of the different groups, we used the generalized linear modeling (SAS GENMOD procedure with gamma model with log link) with adjustment according to patient demographic characteristics and comorbidities, postoperative complications, hospital characteristics, and type of surgical procedure. All results are unweighted values. A value of $P < .05$ was considered to be statistically significant.

Results

We identified 38,226 patients who met the inclusion criteria. Among them, 24,636 (64.4%) underwent RARP and 13,590 (35.6%) underwent ORP. Comparative characteristics of the 2 groups are presented in Table 1. There were no significant age differences between the RARP and ORP group except in the 61- to 65-year-old group; in this group, a greater proportion of patients chose RARP. The proportion of white men was greater among RARP patients and the proportion of black men was higher in the ORP group. The ORP group had more patients with major comorbidities. Patients with private insurance were more likely to undergo RARP and those with Medicaid more frequently had open surgery.

The distribution of both surgical procedures in hospitals with various characteristics (in 616 cases [1.6%] hospital location, control/ownership, size according to number of beds, and teaching status were not identified) are shown in Table 2. The greatest proportion of RARP was found in the West, the smallest in the Midwest. Most of the robotic procedures were performed in the large, urban, private (not for profit), and teaching hospitals and two-thirds of open surgeries were done in the rural hospitals. Interestingly, in a comparison of distribution of surgical procedures in the hospitals of various size categories, the highest proportion of RARP was found in the small hospitals.

The cost of the procedures in the various regions of the United States are shown in Table 3. The lowest total hospital cost for RP and separately for RARP and ORP was found in the South ($P < .0001$). The cost of RP in the Northeast was greater than in the South; it increased further in the Midwest and reached its maximum value in the West ($P < .0001$ for all). Similar to the South, RARP in the Midwest and West was more expensive than ORP ($P < .0001$ for both). However, in the Northeast RARP was significantly less expensive than ORP ($P < .0001$).

We analyzed the cost of RP in hospitals with various characteristics such as hospital location, teaching status, control/ownership, size according to number of beds, and hospital annual volume of RPs (Table 4). In this analysis, only hospital location did not affect cost (urban vs. rural hospitals). All of the remaining hospital characteristics analyzed were associated with differences in cost. RP in teaching and high-volume hospitals was less expensive than in nonteaching and low-volume facilities. Similarly, cost of RP in large hospitals was lower compared with small and especially medium hospitals. Compared with privately owned hospitals, the cost of RP in governmental nonfederal and especially in private not for profit hospitals was significantly greater. However, the latter accounted for 83% of all RPs in our data.

Because the cost of RP varied significantly in hospitals with different characteristics, we compared cost of RP in 4 census regions of the United States using multivariable regression analysis with adjustment according to hospital (region, location, size according to number of beds, control/ownership, teaching status, and hospital volume) and patient (age, race, and comorbidities) characteristics, overall rate of postoperative complications, and type of procedure (RARP and ORP). The South region had the lowest cost for RARP and ORP and was selected as a reference.

Compared with the South, overall cost of RP was significantly greater in the other US regions: by 12.1% in the Northeast, 19.6% in the Midwest, and 40.3% in the West ($P < .0001$ for all). Interestingly, the cost of RP in the Northeast exceeded the cost in the South only by 3.4% and in the Midwest and West this difference was much greater (23.1% and 40.4%, respectively, $P < .0001$). Furthermore, open surgery in the Northeast was 33.8% more costly than in the South; this rate of higher cost was 13.0% in the Midwest and 37.6% in the West ($P < .0001$). In multivariable analysis, the cost of RARP in the Northeast was 12% less than the cost of ORP ($P < .0001$). However, robotic procedures in the Midwest, South, and West remained more expensive than open procedures (43.3%, 37.2%, and 39.1%, respectively; $P < .0001$).

Discussion

Robotic surgical technology has become an integral part of multiple specialties. In the context of PCa, RARP and ORP have been shown to have similar rates of complication, readmissions, and need for additional cancer therapies, whereas transfusion rates, and length of stay was decreased with RARP.[13] Despite these differences, early studies suggested that the benefits of RARP did not translate into decreased costs. In our study we found that the cost of RARP continues to exceed that of ORP, despite the increase in the volume of RARP performed nationwide. Notwithstanding, a regional comparison of costs surprisingly demonstrated that RARP is now a less expensive procedure than ORP in the Northeast region of the United States. Even when potentially confounding factors such as age, race, comorbidities, hospital volume, hospital size, and complications are controlled for, multivariable analysis revealed that the cost of RARP is still approximately 12% lower than ORP in the Northeast. In contrast, in the West, Midwest, and South, RARP was approximately 40% costlier than ORP. At this time, the regional variation in cost is difficult to explain. One possible explanation is the relatively higher cost of ORP in some regions: ORP was significantly more costly in the Northeast. This result is based on 2 observations in our data. First, compared with the Midwest and West regions, RARP was relatively less expensive in the Northeast. Second, ORP in the Northeast was significantly more expensive than in other regions. This increased cost of ORP in the Northeast is interesting, however, reasons for this variability cannot be explained using this data set. We can only speculate that ORP might be reserved for more advanced cases or a preference for ORP compared with other regions. Although there were differences in the cost of RARP, the regional variation in the cost of ORP was more striking. Thus, the lower cost of RARP compared with that of ORP in the Northeast might not be because of the decreased cost of robotic surgery, but rather might reflect the higher cost of ORP in that region. Confirmation of this hypothesis will require an in-depth longitudinal analysis of the cost of ORP. An alternative explanation is that wide regional variations in costs reflect the supply and demand for goods and services for those areas.[11] Thus, the observation that ORP is more expensive than RARP in the Northeast might simply be because of unique regional economic conditions. For example, a previously published study reported that states with higher income and cost of living have lower costs of RP, possibly because of the increased competition and unwillingness of payers to pay such a premium for ORP.[11]

Since its inception, RARP has been an expensive technology.[14] Because ORP has an increased length of stay and transfusion rate, it is surprising that the overall costs associated with RARP have not decreased to that of ORP.[7] Nevertheless, the principle of 'economies of scale' suggests that the cost of RARP should decrease with dissemination of the technology and increased volume. Evidence for this does exist, because decreased cost has been associated with high surgeon volume. However, the same analysis demonstrated that high hospital volume does not translate to significant cost savings.[15] Conversely, Yu et al have shown in a cost analysis of a matched cohort that there is a significant decrease in cost in high-volume hospitals ($8623 vs. $12,754; $P < .01$).[16] In the present study, we note similar findings in that cost in low-volume hospitals is approximately 8% ($P < .0001$) higher than in high-volume centers.

A major strength of this study is the use of the NIS, a nationally representative database that covers all patients with various insurance coverage and uninsured ones. Furthermore, our data were derived from a database that includes all types of patients and providers including all payer data, not just Centers for Medicaid and Medicare Services (CMS) data. In addition, NIS data provides the total cost of hospital admission, which is more accurate than reimbursement data, allowing for a more accurate assessment of regional variation. Despite these advantages, our analysis has some limitations. First, part of the difficulty in assessing exact cost is the multiple ancillary costs, direct and indirect costs that are highly variable such as the initial investment of acquiring a robotic system, yearly maintenance fees, and surgeon fee. Unfortunately these data are not readily available in the NIS.[9] Second, the retrospective cross-sectional nature of the study and reliance on administratively coded data should be taken into consideration, because there might be errors in coding or inconsistencies among different institutions.[17,18] Third, the NIS database does not provide information on cancer severity and pathology. Such information is necessary to determine the indications for surgery, case mix, and disease attributes, which, when analyzed collectively, can more accurately characterize the cost difference between RARP and ORP and identify targets for cost savings. Fourth, the NIS lacks longitudinal analysis of patient-level outcomes. This shortcoming likely results in an underestimation of postoperative complication rates, because some complications will occur after discharge.

Conclusion

The rapid adoption of RARP in the care of men with localized PCa has occurred without a comprehensive analysis of its economic effect. To better assess the true value of robotic technology, a more detailed cost-effectiveness analysis must be carried out. This was a hypothesis-generating study that demonstrated that the cost of RARP is lower than ORP in one part of the United States. Future studies will focus on identifying factors that are specific to regions and might influence costs.

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Clinical Practice Points

- With increasing scrutiny of health care costs, there is a need to evaluate the economic effect of surgical treatment of PCa.
- It has been shown that RARP and ORP have equal oncologic efficacy with RARP conferring the benefits of shorter hospital stay and decreased blood loss.
- However, robotic technology is more costly than the traditional approach.
- In our study we report on regional variation of cost of robot-assisted versus ORP and found that there is significant regional variation.
- Most importantly, when controlling for important factors that contribute to cost, we found that ORP is more costly in the Northeast region.
- However, with the limited data available in our database we cannot pinpoint the reasons for these variations.
- Results of this study help to lay the foundation for future more in-depth cost-effectiveness analyses of the surgical treatment of PCa and possible areas that contribute to variations in cost.

Table 1

Characteristics of the Study Population

Characteristic	Procedure		P	Total
	RARP	ORP		
Mean Age ± SD, Years	61.4 ± 7.2	61.3 ± 7.1	.66	61.34 ± 7.2
Age Group				
18–55 Years	5290 (21.5)	2869 (21.1)	.41	8159
56–60 Years	5357 (21.7)	2947 (21.7)	.89	8304
61–65 Years	6238 (25.3)	3650 (26.9)	.001	9888
66–70 Years	5368 (21.8)	2884 (21.2)	.20	8252
≥71 Years	2383 (9.7)	1240 (9.1)	.08	3623
Race				
White	17,594 (71.4)	9199 (67.7)	<.0002	26,793
Black	2543 (10.3)	1755 (12.9)	<.0002	4298
Hispanic	1262 (5.1)	720 (5.3)	.46	1982
Other and missing	3237 (13.2)	1916 (14.1)	.01	5153
Comorbidities				
Congestive heart failure	113 (0.5)	89 (0.7)	.01	202
Hypertension	12,160 (49.4)	7027 (51.7)	<.0002	19,187
Chronic pulmonary disease	1832 (7.4)	1161 (8.5)	<.0002	2993
Diabetes	3079 (12.5)	1894 (13.9)	<.0002	4973
Renal failure	312 (1.3)	249 (1.8)	<.0002	561
Obesity	1962 (7.9)	1039 (7.7)	.27	3001
Insurance				
Medicare	7613 (30.9)	4238 (31.2)	.57	11,851
Medicaid	417 (1.7)	387 (2.9)	<.0002	804
Private	15,708 (63.8)	8146 (59.9)	<.0002	23,854
Uninsured	277 (1.1)	284 (2.1)	<.0002	561
Other and missing	621 (2.5)	535 (3.9)	<.0002	1156
Total, n	24,636	13,590		38,226

Data are presented as n (%) except where otherwise noted.

Abbreviations: ORP = open radical prostatectomy; RARP = robot-assisted radical prostatectomy.

Table 2

Robot-Assisted and ORP in Hospitals With Various Characteristics

	Procedure		
Hospital Characteristic	**RARP**	**ORP**	***P***
Census Region			
Northeast	4737 (64.6)	2601 (35.4)	<.0001
Midwest	5294 (61.2)	3352 (38.8)	
South	8699 (62.9)	5125 (37.1)	
West	5906 (70.2)	2512 (29.8)	
Location			
Urban	23,640 (65.9)	12,224 (34.1)	<.0001
Rural	564 (32.3)	1182 (67.7)	
Control/Ownership			
Government, nonfederal	1903 (61.3)	1202 (38.7)	<.0001
Private, not for profit	20,404 (65.5)	10,730 (34.5)	
Private, investor-owned	1897 (56.3)	1474 (43.7)	
Size According to Number of Beds			
Small	3832 (73.5)	1379 (26.5)	<.0001
Medium	4533 (60.7)	2937 (39.3)	
Large	15,839 (63.5)	9090 (36.5)	
Teaching Status			
Teaching	16,706 (67.4)	8099 (32.6)	<.0001
Nonteaching	7498 (58.6)	5307 (41.4)	
Total	24,636	13,590	

Data are presented as n (%) except where otherwise noted.

Abbreviations: ORP = open radical prostatectomy; RARP = robot-assisted radical prostatectomy.

Table 3

Cost of RARP and ORP in the US Census Regions

US Region	Cost US$, Median (IQR)			Multivariable Analysis	
	Overall	RARP	ORP	RARP Versus ORP	95% CI
Northeast	10,473 (5839)	10,126 (5288)	11,423 (7400)	−12.8%	−12.9% to −12.8%; $P < .0001$
Midwest	11,162 (6261)	12,662 (6927)	9452 (5027)	35.9%	35.9%–36%; $P < .0001$
South	9220 (4544)	9720 (4744)	8132 (4325)	31.6%	31.5%–31.7%; $P < .0001$
West	13,125 (6825)	13,913 (6570)	10,934 (6750)	33.0%	32.9%–33.1%; $P < .0001$

Abbreviations: IQR = interquartile range; ORP = open radical prostatectomy; RARP = robot-assisted radical prostatectomy.

Table 4

Total Hospital Cost of Radical Prostatectomy in Various Hospitals

Location		
Urban	**Rural**	
10,707 (6049)	10,918 (6587)	
P = .24		
Teaching Status		
Teaching	**Non-teaching**	
10,509 (5804)	11,064 (6596)	
P <.0001		
Control/Ownership		
Private, Investor-owned	**Government, Nonfederal**	**Private, Not for Profit**
10,143 (4166)	10,673 (5764)	10,840 (6294)
P <.0001	*P* = .16	
Size According to Number of Beds		
Large	**Small**	**Medium**
10,348 (6200)	10,801 (4623)	11,674 (6332)
P <.0001	*P* <.0001	
Hospital Volume		
High	**Low**	
10,587 (5876)	10,782 (6553)	
P = .016		

Median costs are given in US$ (IQR).