



# Regional differences in total hospital charges between open and robotically assisted radical prostatectomy in the United States

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## Abstract

**Background** Robotically assisted radical prostatectomy (RARP) has become the most frequently used surgical approach for patients treated with radical prostatectomy (RP) for localized prostate cancer (PCa). Previous studies reported higher total hospital charges (THCs) for RARP than open RP (ORP). We hypothesized that based on increasing RARP surgical expertise, differences in THCs between RARP and ORP should have decreased or even disappeared in the United States in most contemporary years.

**Patients and methods** Within the National Inpatient Sample database (2008–2015), we identified patients who underwent RARP or ORP. Multivariable linear regression models with adjustment for clustering were used to test for differences in THCs. Subgroup analyses focused on geographical regions, defined as West, Midwest, South and Northeast.

**Results** Of 83,693 RP patients, 51,363 (61.4%) underwent RARP. RARP rates increased from 13.1 to 81.5% ( $p=0.04$ ). Overall, median THCs were \$11,898 vs. \$10,162 ( $p<0.001$ ) for RARP vs. ORP, respectively. After adjustment for complications, length of stay and clustering, RARP was associated with higher THCs (\$3124 more for each RARP,  $p<0.001$ ). Additional charges for RARP did not change over time ( $p=0.3$ ). However, additional charges for RARP were highest in the West (\$4610,  $p<0.001$ ), followed by the Midwest (\$3278,  $p<0.001$ ), the South (\$2906,  $p<0.001$ ) and the Northeast (\$2216,  $p<0.001$ ).

**Conclusion** RARP rates have increased exponentially from 13.1 to over 80%. Similar rates were identified across all four geographical regions. RARP THCs exceeded those of ORP. Finally, important regional differences in RARP THCs were identified and persisted even after most detailed adjustment for population differences.

**Keywords** Robotic-assisted · Hospital charges · National inpatient sample · Prostatectomy · Regions

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## Introduction

Robotically assisted radical prostatectomy (RARP) has become the most frequently followed surgical approach for patients treated with radical prostatectomy (RP) for localized

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prostate cancer (PCa) [1–3]. Previous studies reported higher total hospital charges (THCs) attributable to RARP vs. open RP (ORP) [3–7]. Moreover, Faiena et al. also reported variations in THCs according to geographic region within the United States (US). Specifically, charges associated with RARP were lower than charges associated with ORP in the Northeast, but the opposite was found in the three remaining National Inpatient Sample (NIS) database regions, where RARP THCs exceeded those of ORP [8]. However, this and other similar analyses were based on a time period when RARP was still in its infancy phase, except for the report by Leow et al., where a more contemporary relationship was described [1, 3, 4, 8, 9].

It is also noteworthy that several previous investigators reported lower perioperative complications for RARP than ORP, in clinically localized PCa patients [1–3]. Since complications result in higher THCs, it could be argued that lower complications at RARP should lead to reduced hospital charges. Moreover, continuous improvements in surgical experience with RARP should also result in shorter operating room time. Such practice should further reduce hospital charges, since operative time is one of the main cost drivers [5, 10]. Last but not least, length of stay (LOS) after RARP has also decreased. The latter should also translate into lower RARP THCs [10].

Based on the above considerations, we hypothesized that hospital charges attributable to RARP should have decreased in the US in most contemporary years. To test our hypothesis, we examined total hospital charges between RARP vs. ORP, using the NIS database. Subgroup analyses focused on the four main NIS database geographical regions.

## Materials and methods

### Data source

To assess THCs of RARP vs. ORP patients, we relied on the NIS database (2008–2015). The NIS is a set of longitudinal hospital inpatient databases included in the Healthcare Cost and Utilization Project family, created by the Agency for Healthcare Research and Quality through a Federal–State partnership [11]. The database includes 20% of US inpatient hospitalizations, with discharge abstracts from eight million hospital stays.

### Study population

Within the NIS database, we focused on patients with a primary diagnosis of PCa (ICD-9-CM code 185), aged  $\geq 18$  years. Patients with a secondary diagnosis of metastatic disease (ICD-9-CM code 197.x and 198.x) were excluded. Primary procedure codes were used to identify

RP (ICD-9-CM code 60.5) patients. Secondary procedure codes were used to identify robotic procedures according to the modifier codes 17.4 and 17.42 [8, 12]. Moreover, secondary procedure codes with the modifier 40.3 and 40.5 (ICD-9-CM) were used to identify lymph node dissection procedures.

### Outcomes of interest

Complications rates were defined using secondary ICD-9 diagnostic codes, as previously described [13, 14]. Intraoperative complications consisted of accidental blood vessel and/or nerve and/or organ puncture or laceration during the procedure. Postoperative complications consisted of cardiac, respiratory, vascular, operative wound, genitourinary, blood transfusions, bowel obstruction, miscellaneous medical and miscellaneous surgical [12]. As provided by the NIS, LOS is calculated by subtracting the admission date from the discharge date [15]. Inflation-adjusted THCs were defined according to NIS methodology [16].

### Patient and hospital characteristics

Patient age, year of surgery, race/ethnicity (Caucasian, African American, Hispanic and other), Charlson comorbidity index (CCI) [17, 18] and insurance status (private insurance, Medicare, Medicaid, and other [self-pay]) were ascertained from the NIS [15]. Additional risk variables consisted of hospital region (Northeast, Midwest, South, West) [19], income, hospital bed-size (small, medium vs. large) and hospital teaching vs. non-teaching status. Teaching institutions had an American Medical Association-approved residency program, were a member of the Council of Teaching Hospitals, or had a ratio of 0.25 or higher of full-time equivalent interns and residents to non-nursing home beds [11]. Finally, annual hospital volume (low, medium vs. large tertile), representing the number of performed procedures at each participating institution during each study calendar year, was calculated.

### Statistical analysis

First, medians and interquartile ranges, as well as frequencies and proportions, were reported for continuous (age, LOS, year of surgery and total hospital charges) and categorical variables (race, year of surgery, insurance status, CCI, annual hospital volume, region, hospital bed-size, income, teaching status, lymph node dissection and complications), respectively. The statistical significance of differences in medians and proportions was evaluated with the Kruskal–Wallis and  $\chi^2$  tests.

Second, estimated annual percentage change (EAPC), was defined according to surgical approach and was depicted

graphically. Third, median THCs were also depicted graphically according to surgical approach (RARP vs. ORP). Fourth, multivariable linear regression models (MLRMs) tested for THCs' differences, according RARP vs. ORP. Fifth, MLRMs were repeated for each year of observation to generate year-specific RARP vs. ORP differences in THCs. Sixth, four additional MLRMs tested for THCs' differences, according to database regions, namely the Northeast, the Midwest, the South and the West. All multivariable models were fitted using generalized estimating equations to further adjust for clustering [2].

All statistical tests were two-sided. The level of significance was set at  $p < 0.05$ . Analyses were performed using the R software environment for statistical computing and graphics (version 3.4.1; <http://www.r-project.org/>).

## Results

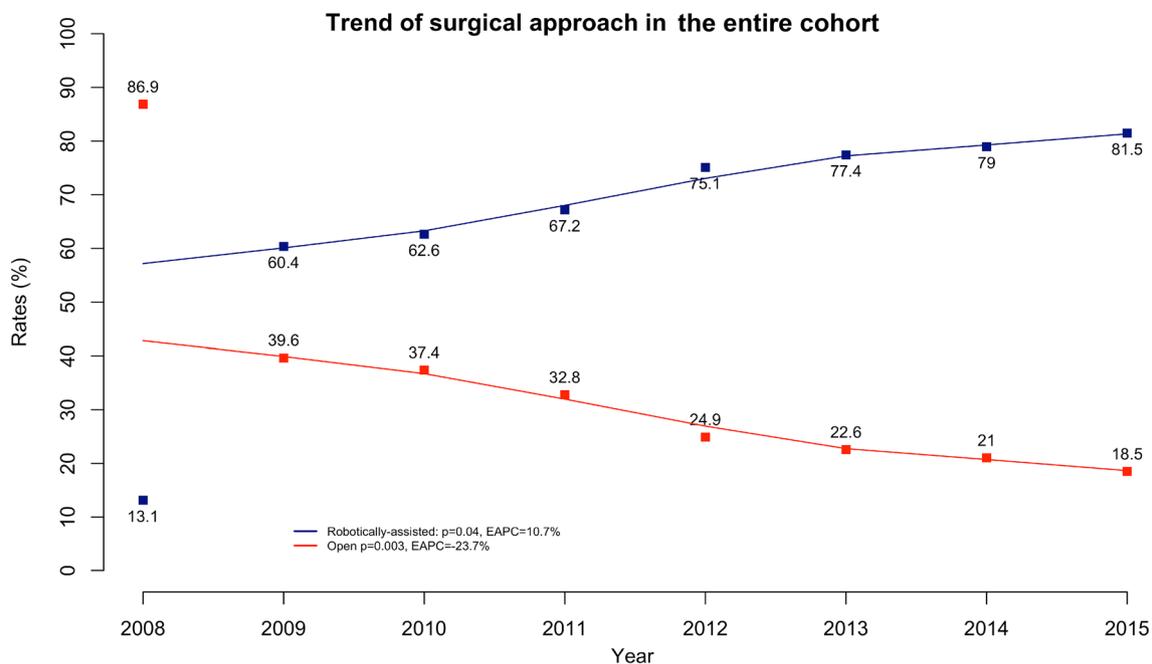
### Descriptive characteristics and rates of RP over time

Among 83,693 RP patients, 51,363 (61.4%) vs. 32,330 (38.5%) underwent RARP vs. ORP (Supplementary Table 1), respectively. The overall median THCs were significantly higher in RARP patients (\$11,898 vs. \$10,162, interquartile range [IQR]: \$9265–\$15,605 vs. \$7554–\$13,699,  $p < 0.001$ ), compared to ORP patients and for both approaches the median THCs did not change

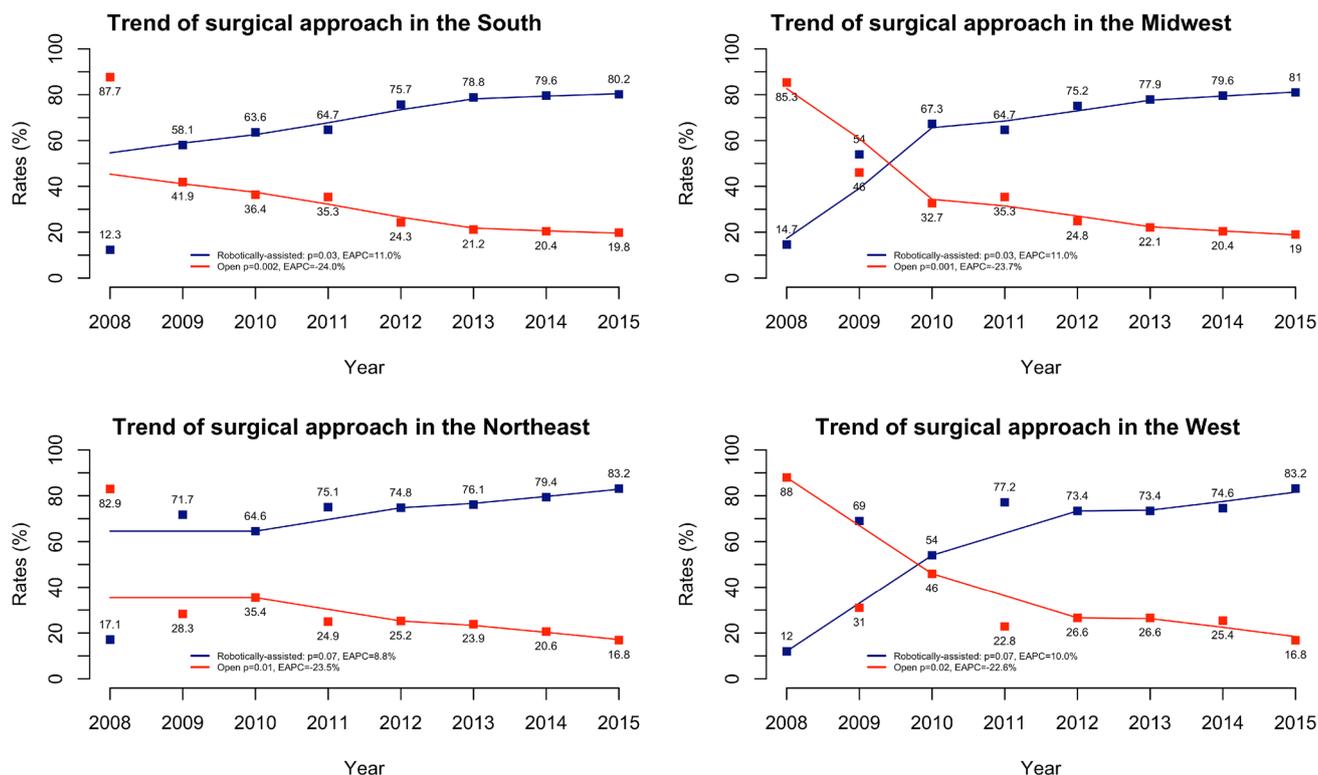
significantly during the study span (RARP:  $p = 0.2$ , ORP:  $p = 0.9$ , Supplementary Fig. 1). Moreover, RARP patients had shorter median LOS (1 vs. 2 days, IQR: 1–2 vs. 1–3,  $p < 0.001$ ), more frequently received treatment at teaching hospitals (73.4 vs. 61.0%,  $p < 0.001$ ) and less frequently underwent lymph node dissection (37.7 vs. 49.6%,  $p = 0.001$ ).

Between 2008 and 2015, overall RARP rates increased from 13.1 to 81.5% (EAPC: 10.7%;  $p = 0.04$ ). Conversely, the overall ORP rates decreased from 86.9 to 18.5% (EAPC:  $-23.7%$ ;  $p = 0.003$ ) (Fig. 1). After stratification, according to database regions (Fig. 2), RARP rates in the South, the Midwest, the Northeast and the West increased from 12.3 to 80.2% (EAPC: 11.0%,  $p = 0.03$ ), 14.7–81.0% (EAPC: 11.0%,  $p = 0.03$ ), 17.1–83.2% (EAPC: 8.8%,  $p = 0.07$ ) and 12.0–83.2% (EAPC: 10.0,  $p = 0.07$ ), between 2008 and 2015, respectively. Conversely, ORP rates decreased accordingly from 87.7 to 19.8% (EAPC:  $-24.0$ ,  $p = 0.002$ ), 85.3–19.0% (EAPC:  $-23.7$ ,  $p = 0.001$ ), 82.9–16.8% (EAPC:  $-23.5$ ,  $p = 0.001$ ) and 88.0–16.8% (EAPC:  $-22.6$ ,  $p = 0.02$ ). Adjustment for THCGs was performed according to complication rates, LOS and in-hospital mortality.

Except for in-hospital mortality ( $p = 0.1$ ) and parenteral nutrition use ( $p = 0.1$ ), RARP patients less frequently experienced all types of examined complications and less frequently underwent blood transfusions (all  $p < 0.05$ ) (Supplementary Table 2), compared to ORP patients.



**Fig. 1** Trend of surgical approach used for radical prostatectomy, within the National Inpatient Sample between 2008 and 2015



**Fig. 2** Trend of surgical approach used for radical prostatectomy, within the National Inpatient Sample between 2008 and 2015, according to database regions: South vs. Midwest vs. Northeast vs. West

### Multivariable linear regression models predicting THCs

MLRMs (Table 1) predicting THCs that adjusted for all covariates, LOS, complications and clustering, revealed that THCs were \$3124 (95%-confidence interval [CI]: \$2816–\$3432,  $p < 0.001$ ) higher for each RARP vs. ORP. When analyses were repeated for each individual year of observation, between 2008 and 2015, the difference between RARP and ORP did not change in a statistically significant fashion ( $p = 0.3$ ) (Fig. 3).

### THCs according to geographic regions

The median THCs for either RARP and/or ORP were highest in the West (\$13,385, IQR: \$10,085–\$19,096), followed by the Midwest (\$12,393, IQR: \$9498–\$15,794), the Northeast (\$10,517, IQR: \$7966–\$14,047) and lowest in the South (\$10,139, IQR: \$8050–\$13,127).

Similar tendencies were recorded after stratification according to surgical approach (RARP vs. ORP). The median THCs for RARP were highest in the West (\$14,467, IQR: \$11,205–\$20,442), followed by the Midwest (\$13,460, IQR: \$10,684–\$17,005), the South (\$10,802, IQR: \$8662–\$13,732) and the Northeast (\$10,265, IQR:

\$7991–\$13,254). The median THCs for ORP were, respectively, in the West (\$11,794, IQR: \$8368–\$16,673), the Midwest (\$10,704, IQR: \$7816–\$13,601), the South (\$9199, IQR: \$7097–\$11,900) and the Northeast (\$11,355, IQR: \$7913–\$15,554).

Finally, the adjusted THCs showed the same tendencies, where RARP was costlier than ORP, even after multivariable adjustment for complications, LOS, in-hospital mortality and clustering in MLRMs. The highest additional average THCs for RARP vs. ORP were recorded in the West (\$4610, 95%-CI: \$3710–\$5512,  $p < 0.001$ ), followed by the Midwest (\$3278, 95%-CI: \$2730–\$3826,  $p < 0.001$ ) and the South (\$2906, 95%-CI: \$2481–\$3332,  $p < 0.001$ ). Moreover, adjusted THCs for RARP vs. ORP were also higher in the Northeast (\$2216, 95%-CI: \$1587–\$2845,  $p < 0.001$ ) (Supplementary Table 3).

### Discussion

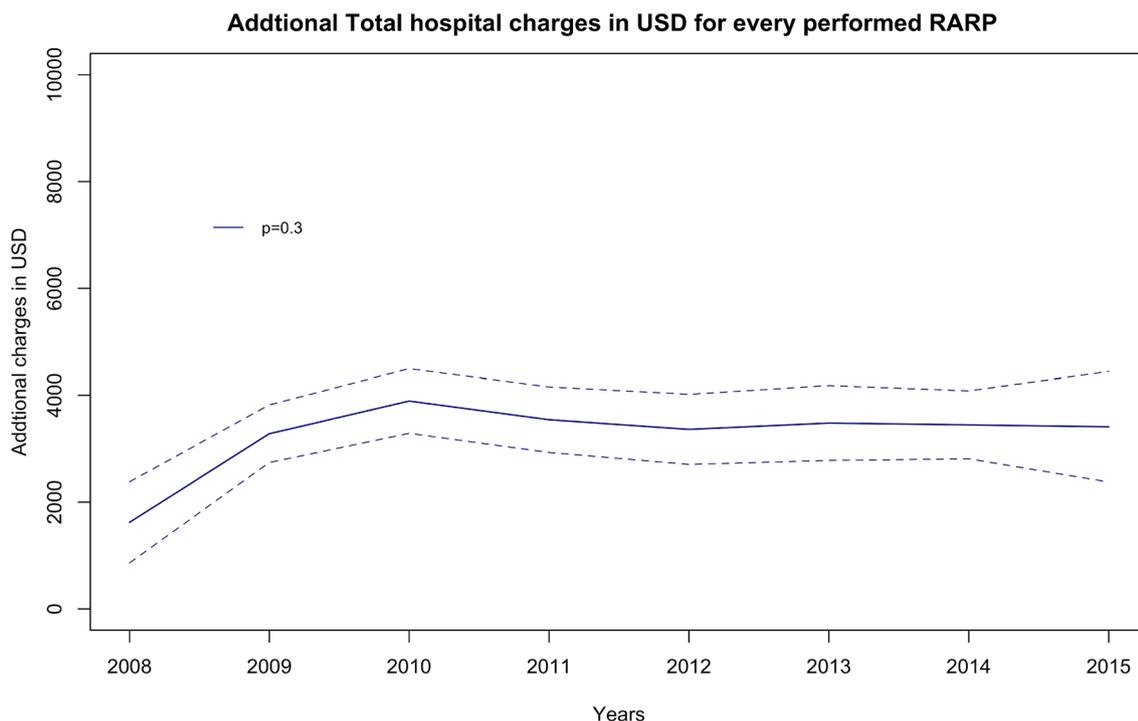
RARP represents the most frequent surgical approach for localized PCa RP patients [1–3]. Previous studies based on historical data, when RARP was still in its infancy phase, showed higher THCs attributable to RARP vs. ORP and also showed variability according to geographic regions [3–5,

**Table 1** Multivariable linear regression models predicting total hospital charges associated with radical prostatectomy, within the National Inpatient Sample between 2008 and 2015, after adjustment for clustering

	Additional hospital charges in USD	2.5%	97.5%	P value
Open RP (reference)	–	–	–	
RARP	\$3124	\$2816	\$3432	< 0.001
Year of surgery	\$154	\$86	\$221	< 0.001
Age (years)	\$1	– \$4	\$6	0.7
Length of stay (days)	\$1629	\$1311	\$1948	< 0.001
Charlson comorbidity index 0 (reference)	–	–	–	
Charlson comorbidity index 1	\$234	\$147	\$321	< 0.001
Charlson comorbidity index $\geq 2$	\$400	\$190	\$611	< 0.001
Private insured (reference)				
Medicaid	\$152	– \$134	\$439	0.3
Medicare	– \$53	– \$139	\$32	0.2
Other	– \$69	– \$222	\$84	0.4
Caucasian race (reference)				
Afro-American race	\$88	– \$35	\$211	0.2
Hispanic race	\$97	– \$59	\$253	0.2
Race other	– \$169	– \$296	– \$42	< 0.01
Non-teaching hospital (reference)	–	–	–	
Teaching hospital	– \$143	– \$380	\$95	0.2
Income in first quartile (reference)	–	–	–	
Income in second quartile	– \$2	– \$91	\$88	0.97
Income in third quartile	\$28	– \$53	\$109	0.5
Income in fourth quartile	– \$17	– \$116	\$82	0.7
Income unknown	– \$73	– \$233	\$86	0.4
Annual hospital volume high (reference)	–	–	–	
Annual hospital volume low	\$467	– \$19	\$952	0.1
Annual hospital volume medium	\$1309	\$827	\$1792	< 0.001
South hospital region (reference)	–	–	–	
Midwest hospital region	\$1333	\$1107	\$1560	< 0.001
Northeast hospital region	– \$300	– \$567	– \$33	0.03
West hospital region	\$4600	\$4251	\$4949	< 0.001
Large hospital bed-size (reference)	–	–	–	
Small hospital bed-size	\$765	\$444	\$1086	< 0.001
Medium hospital bed-size	– \$166	– \$380	\$47	0.1
Lymph node dissection performed	\$1	– \$109	\$111	0.99
Intraoperative complication	– \$272	– \$1195	\$651	0.6
In-hospital death	\$16,950	\$6766	\$27,134	0.001
Cardiac complication	\$2269	\$1542	\$2996	< 0.001
Pulmonary complication	\$2677	\$1739	\$3615	< 0.001
Miscellaneous medical complication	\$24	– \$678	\$726	0.9
Miscellaneous surgical complication	\$2284	\$1436	\$3132	< 0.001
Genitourinary complication	\$1605	\$691	\$2520	< 0.001
Vascular complication	\$2802	\$1143	\$4461	< 0.001
Wound complication	\$6691	\$3115	\$10,268	< 0.001
Blood transfusion	\$830	\$341	\$1319	< 0.001
Parenteral nutrition use	\$3024	– \$2167	\$8215	0.3

8]. We hypothesized that THCs attributable to RARP have decreased within more contemporary years. This hypothesis was based on the concept of improved surgical expertise in

RARP that should result in fewer complications and shorter LOS. We tested our hypothesis by virtue of comparing THCs between RARP vs. ORP, after detailed adjustments, within



**Fig. 3** Trend of additional average total hospital charges attributable to robotically assisted vs. open radical prostatectomy, within the National Inpatient Sample between 2008 and 2015

a large population data registry. Our analyses demonstrated several noteworthy findings.

First, the proportion of RARP rates relative to ORP rates increased from 13.1 to 81.5% ( $p = 0.04$ ) during the study span. Similar trends were recorded after stratification according to four geographic regions (West, Midwest, South and Northeast). These results corroborate previous studies that reported on higher RARP rates compared to ORP [1–3]. Moreover, this observation is also indicative of the pivotal role of RARP in the surgical treatment of PCa patients.

Second, median THCs were significantly higher after RARP vs. ORP. Moreover, in MLRMs adjusted for complications, in-hospital mortality, LOS and clustering, RARP resulted in an average \$3124 higher THCs, compared to ORP. Surprisingly, this difference did not decrease over the study span. Based on the 51,363 RARP cases performed between 2008 and 2015 within the current database that accounts for approximately 20% of US inpatient hospitalizations, RARPs contributed to an additional expenditure of \$160,458,012, relative to an estimate based on exclusive use of ORP. This amount might increase to \$802,290,060, provided a similar relationship between RARP/ORP THCs within the rest of the country. Our observations add to the previous reports based on more historical cohorts, where RARP resulted in higher THCs in the US [1, 3, 4, 9, 20]. The additional THCs for RARP vs. ORP reported by Kim et al. (\$2542) are similar to our results (\$3124) [4]. However,

our results demonstrated a THCs increment of \$3124 for RARP relative to ORP, which is lower than that reported by Leow et al. (\$4528) [3]. The explanation for this discrepancy may be related to the more contemporary nature of our database (2008–2015 vs. 2003–2013). The latter may reflect lower rates of complications, shorter individual hospital stay and more favorable other outcomes that are not available within population-based data repositories, such as the NIS. The additional explanation for a lower incremental cost of RARP in our study compared to Leow et al. originates from multivariable adjustment for variables that tend to inflate cost, namely complications, in-hospital mortality and LOS. Unadjusted RARP THC figures show remarkable similarities between Leow et al. study (\$11,311), Cole et al. (\$11,878) [21] and our study (\$11,898). These similarities originate from absence of adjustment relative to ORP, where differences in complications, LOS and in-hospital mortality are eliminated with the use of multivariable models. It is also of note that recent European findings reported by Hyldgard et al. also showed a cost increment of €2459, when RARP was performed instead of ORP [22]. Last but not least, an increment in costs is also a well-known phenomenon in other countries. For example, other centers of excellence in Sweden quantified the cost increment at €3837 [23].

Taken together, our findings, as well as those of several North American and European investigators, indicate a cost disadvantage, when RARP is performed instead of ORP.

These observations need to be interpreted with caution, since cost does not represent a key determinant in individual patient's care. Instead, lower complications, shorter LOS and lower in-hospital mortality represent far more important individual determinants of quality of care. Additional data also demonstrated that RARP may hold an advantage over ORP with respect to earlier return to continence [24] or surgical margin rates for intermediate- and high-risk PCa patients [25]. However, we could not examine these endpoints within the current database. Instead, our analyses exclusively focused on THCs. THCs as an endpoint remain an important consideration in the use of health dollars, given a well-established problem with increasing health care expenditures, worldwide. In consequence, a national saving of \$802,290,060 that was extrapolated from the findings of our analyses, if ORP was exclusively performed instead of RARP, could certainly be used in other areas of health care delivery.

Several explanations can be proposed to explain the cost discrepancy between RARP and ORP. Expenditures relate to the robot, not excluding its purchase and service contract. Expenditures also originate from use of disposable materials [23]. Some of these costs might be offset, but earlier return to work or earlier resumption of normal functioning. This said, our database does not provide us with the opportunity to examine these variables and analyze them in an objective fashion. In consequence, we cannot validly comment about the relative importance of individual variables that contribute to higher RARP cost.

Third, our analyses also revealed important regional differences in THCs after either RARP or ORP. In all region-specific analyses, RARP THCs were higher than ORP THCs. Specifically, after most detailed adjustment the highest average additional charges attributed to RARP were recorded in the West (\$4610), followed by the Midwest (\$3278), the South (\$2906) and the Northeast (\$2216). The available patient and hospital characteristics, as well as complication rates and LOS characteristics could not fully or partially explain the regional discrepancies in RARP and/or ORP charges. Our results regarding the absolute value of median THCs are virtually the same as those reported by Faiena et al. [8]. However, our multivariable results differ from those of Faiena et al., based on lack of adjustment for clustering in the Faiena et al. analyses. This methodological approach is essential, since clustering of complications within the same institution represents a well described phenomenon in surgical literature, including urologic oncology [26].

Taken together, our results demonstrate that RARP represents the dominant surgical modality relative to ORP in the US. However, RARP is associated with higher THCs compared to ORP. The THCs disadvantage of RARP relative to ORP did not change during the study span, unlike

we postulated. Moreover, we identified important regional differences in THCs after RARP or ORP. It is noteworthy that despite being significant, the difference in median LOS between RARP vs. ORP was small (1 vs 2 days). This could be an explanation, why, despite adjustment for LOS, the disadvantage of RARP relative to ORP did not change during the study span.

Despite the better complication profile and shorter LOS for RARP, previous studies demonstrated that RARP did not result in a faster return to work or better quality of life after surgery compared to ORP [27, 28]. Therefore, it should be questioned whether the benefits of potentially sooner return to work may justify the additional cost of RARP. Ideally, the answer to such questions should be provided through prospective randomized trials. However, we are unaware of any such trial addressing this important question.

Beside its retrospective nature, our study also suffers of several other limitations that are inherent to population-based analyses. For example, we were unable to adjust for tumor characteristics. However, we believe that tumor characteristics are equally distributed between RARP and ORP patients. Moreover, we were also unable to adjust for patient characteristics, such as performance status, American Society of Anesthesiologists physical status and differences in laboratory values, as well as presence or absence of exposure to neoadjuvant chemotherapy, androgen deprivation and radiotherapy. Furthermore, the NIS does not contain individual surgeon volume, which influences THCs, as previously described [21, 29]. Therefore, it is possible that the lack of individual surgeon volume might have influenced our results. Additionally, lack of considering of robot startup costs, including the initial purchase, represents another limitation. Based on the costs of purchasing a robot, the costs of disposables and the time and effort necessary to train the whole surgical team appropriately, some of the added expenses are reflected within THCs related to RARP procedure. Would these costs have been considered, the additional THCs associated with RARP would may have reduced. Last but not least, only inpatient information was available in the NIS database and no data were available regarding readmissions and late complications, which ideally need to be included when analyses focusing on THCs are performed [12].

## Conclusion

In conclusion, RARP rates have increased exponentially from 13.1 to over 80%. Similar rates were identified across all geographical regions. RARP THCs exceeded those of ORP, even after adjustment for complications, LOS and other important confounding variables. Finally, important regional differences in RARP THCs were identified and

persisted even after most detailed adjustment for population differences.

**Authors' contribution** FP protocol/project development, data analysis, manuscript writing/editing. SN data analysis. EM Manuscript writing/editing. SK data collection or management. MB Data analysis. ZT data collection or management. AH protocol/project development, manuscript writing/editing. FS manuscript writing/editing. KCZ Data analysis. FM manuscript writing/editing. SFS manuscript writing/editing. MG manuscript writing/editing. DT protocol/project development, manuscript writing/editing. PIK protocol/project development, data analysis, manuscript writing/editing.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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