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Original Article

Clinical outcomes and postoperative costs of robot-assisted radical prostatectomy in patients with prostate cancer in South Korea: Nationwide cohort study

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ABSTRACT

Background: No national comparison has been conducted between robot-assisted radical prostatectomy (RARP) and other surgical techniques for prostate cancer in South Korea. This study aimed to assess the clinical outcomes and postoperative costs of RARP relative to other radical prostatectomy methods.

Methods: We analyzed data from the National Health Insurance Service database for patients diagnosed with prostate cancer from 2004 to 2016. Patients who underwent RARP were matched with those who received other surgical treatments using propensity score matching. We then evaluated clinical outcomes and postoperative costs.

Results: Both groups comprised 12,108 patients, matched precisely by age, year of diagnosis, Charlson comorbidity index, hospital location, and hospital type. The RARP group experienced significantly lower transfusion rates (7.7 % vs. 39.2 %, $p < 0.001$), shorter hospital stays (8.96 days vs. 11.88 days, $p < 0.001$), and lower postoperative costs 1 year after surgery (\$2775.40 vs. \$2953.00, $p = 0.004$) compared to the non-RARP group.

Conclusions: RARP was associated with better clinical outcomes and lower postoperative costs than other surgical methods, largely due to reduced complications and improved management of incontinence and ADT use. Although multivariate analysis did not show significant superiority, RARP may still present a cost-effective approach for prostate cancer treatment by enhancing clinical outcomes and decreasing healthcare costs.

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1. Introduction

Radical prostatectomy is a common treatment for localized prostate cancer in patients with a life expectancy greater than 10 years.¹ There are currently three main surgical methods for prostate cancer: robot-assisted laparoscopic radical prostatectomy (RARP), laparoscopic radical prostatectomy (LRP), and open radical prostatectomy (ORP).² With advancements in technology, robotic

surgery has been introduced for various organs, leading to an increase in the proportion of radical prostatectomies performed in urology compared to laparoscopic or open procedures.³ A study using the 2016 SEER-Medicare database showed that the use of RARP increased from 13.6 % in 2003–2004 to 72.6 % in 2011–2012.⁴ Robotic surgery offers several advantages, including three-dimensional visibility, ease of operation, and a relatively short learning curve.⁵ From the patient's perspective, this minimally invasive surgical technique results in fewer surgical scars, reducing pain at the operation site, the need for analgesics, and the risk of wound complications.⁶ Furthermore, robot-assisted surgery facilitates early mobilization, shortens the hospitalization period, and promotes rapid recovery.⁷ RARP is known to reduce the need for blood transfusions, and some studies suggest it may lead to better functional outcomes, such as improved initial urinary

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continence and erectile function.^{8,9} However, it is well-established that there is little difference in oncological outcomes between laparotomy and laparoscopic surgery, including robotic surgery.¹⁰

It is also well-established that robotic surgery is comparatively more expensive than other surgical methods. This increased cost may be related to the high expenses of robotic machines, maintenance, disposable equipment, and longer surgery times.¹¹ Several studies have examined the cost of robotic surgery, but clear evidence regarding the total medical cost for the RARP group is still lacking.¹² In South Korea, RARP has not been compared with other surgical methods for prostate cancer on a national level. Therefore, we divided the patients into two groups based on whether they underwent robotic surgery or another surgical method, and we compared the impact of these approaches on clinical outcomes and postoperative costs.

2. Materials and methods

2.1. Data source

The data for this study were extracted from the National Health Insurance Service (NHIS) data repository, known as the Health Insurance and Review Assessment (HIRA). This repository collects claims data during the healthcare provider reimbursement process and provides compulsory insurance coverage for approximately 98 % of all Korean citizens and long-term residents. The HIRA offers comprehensive and detailed information on medical services, including treatments, medications, procedures, and diagnoses coded according to the International Classification of Diseases and Related Health Problems, 10th edition (ICD-10), for around 50 million beneficiaries under a universal healthcare system (Supplementary Table S1, Supplementary Table S2).

2.2. Study cohort

The cohort included patients who were diagnosed with resectable PC and underwent RP between January 1, 2007, and December 31, 2018, as identified from the NHIS. The enrollment period was from January 1, 2004, to December 31, 2016. The washout period was defined as the time before the index date, which was the first date when the surgery or anesthesia code was claimed following the diagnosis of prostate cancer. Patients were followed from January 1, 2006, to December 31, 2018 (from the index date to the endpoint). The endpoint was defined as the date of outcome occurrence or the end of the study period (December 31, 2018). Exclusion criteria were as follows: (1) surgery before 2002, (2) previous diagnosis of other cancers, (3) surgery during the washout period, (4) missing data on surgery or anesthesia, (5) incorrect information, (6) ineligible surgery definition. After forming the cohort, the RARP and other surgery groups were matched by propensity score.

2.3. Endpoints and statistical analysis

The primary outcome of the study was to compare the postoperative costs between RARP and other surgical methods. Covariates such as operating time (>4 h), transfusion rates, length of hospital stay (days), ADT usage, salvage RT, readmission rates, incontinence, and overall mortality were compared between the two groups. The secondary outcome was to assess the association between clinical outcomes and postoperative costs. Covariates included age (in years), year of diagnosis, Charlson Comorbidity Index (CCI) score, hospital type (teaching or nonteaching), and hospital location (capital or provincial area). Outpatient and hospitalization costs were compared between the groups, and

postoperative costs were calculated based on the surgical approach. Univariate and multivariable regression analyses were conducted to examine factors influencing postoperative costs. Appropriate statistical tests, including t-tests, chi-square tests, and log-rank tests, were used. Statistical analyses were performed using SAS Enterprise Guide version 9.4 (SAS Inc., Cary, NC, USA) and R Studio version 3.5.2. Statistical significance was defined as a P-value <0.05.

3. Results

3.1. Participant characteristics

The study analyzed 913,970 individuals who received prostate cancer diagnostic codes between 2004 and 2018. After applying exclusion criteria, 30,312 patients met the study conditions, with 16,340 undergoing robotic surgery and 13,972 undergoing other surgical procedures. Following 1:1 matching through propensity score matching (PSM), there were 24,216 patients in the matched cohorts, with 12,108 patients in each group (Fig. 1). There was no significant difference between the two groups after applying PSM (SMD <0.001), as shown in Table 1.

3.2. Comparison of primary and secondary outcomes between groups

When comparing outcomes between the two groups, the robotic surgery group demonstrated superior results in several areas, including lower rates of transfusion (935 vs. 4,742, $p < 0.001$), shorter hospital stays (8.96 days vs. 11.88 days, $p < 0.001$), reduced ADT usage (2796 vs. 3,133, $p < 0.001$), fewer readmissions (2410 vs. 3,030, $p < 0.001$), and a lower incidence of incontinence (8464 vs. 8,919, $p < 0.001$). However, the robotic surgery group had a higher number of operations lasting more than 4 h (6218 vs. 5,852, $p < 0.001$) and more cases requiring salvage RT (1697 vs. 1,566, $p = 0.014$) compared to the other surgery group (Table 2).

Fig. 2 shows the analysis results of the subgroup. The difference in postoperative total costs between the two groups was \$172.70 ($p = 0.607$) in 2007–2009, \$626.40 ($p = 0.038$) in 2010–2012, and \$1618.90 ($p < 0.001$) in 2013–2016, based on the year of diagnosis. The difference in postoperative costs between the two groups was expected to gradually increase as the diagnostic year becomes more recent, relative to the early years of robotic surgery. The RARP group had lower postoperative costs than the other surgery group, and this difference increased with a higher CCI score. The total postoperative costs varied between the two groups based on the CCI score. In groups 0–1, the difference was \$291.90 ($p = 0.270$); in groups 2–3, it was \$783.90 ($p = 0.003$); and in group ≥ 4 , it was \$2005.70 ($p < 0.001$). The total postoperative costs also varied significantly based on the type and location of the hospital. In teaching hospitals, the cost difference was \$331.00 ($p = 0.198$), while in nonteaching hospitals, it was \$1384.20 ($p < 0.001$). Similarly, in the capital area, the cost difference was \$1124.50 ($p < 0.001$), and in provincial areas, it was \$725.30 ($p = 0.002$).

The study divided expenses into hospitalization, outpatient, and total costs based on the surgical approach, and the accumulated postoperative cost over time was calculated (Fig. 3). Hospitalization costs did not differ significantly between the two groups over the 5-year period; however, outpatient postoperative costs were consistently higher in the other surgery group ($p < 0.01$ for all years). Consequently, the total postoperative cost was ultimately higher in the other surgery group.

A multivariate analysis was conducted to determine the factors affecting the 5-year postoperative cost. The analysis revealed that the length of hospital stay ($p < 0.001$), transfusion ($p = 0.002$), ADT

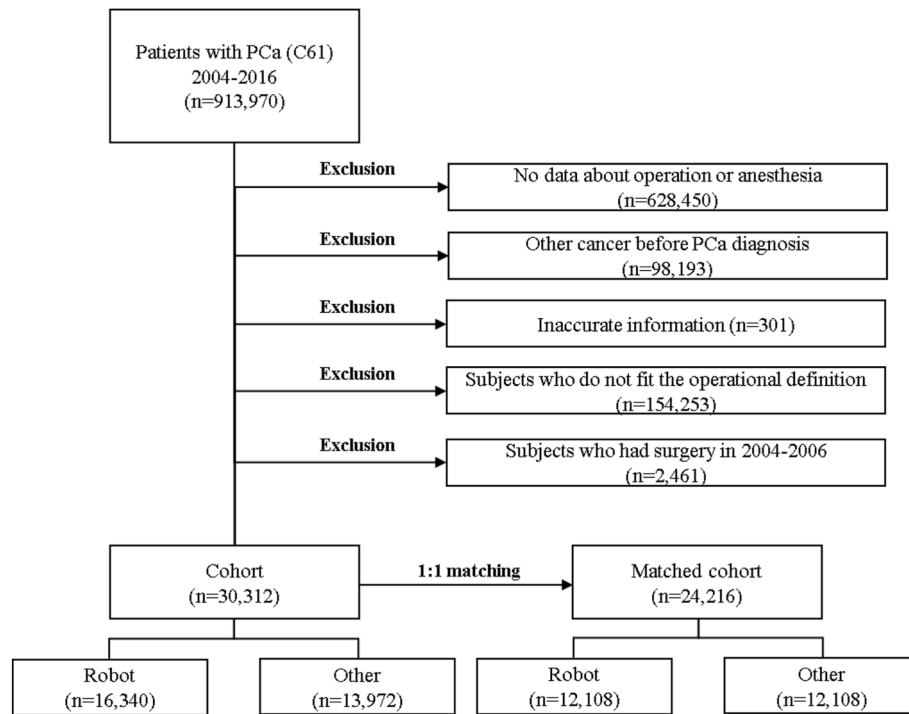


Fig. 1. Study design flow chart.

Table 1
Baseline characteristics of the study sample.

	Unmatched patients (n = 30,312)				Matched patients (n = 24,216)			
	Robot (n = 16,340)	Other (n = 13,972)	p-value	SMD	Robot (n = 12,108)	Other (n = 12,108)	p-value	SMD
Age (years)	65.672 (± 7.466)	67.635 (± 6.459)		–	66.987 (± 7.058)	67.484 (± 6.631)		–
55–64	6022 (36.854 %)	3336 (23.876 %)	<0.001	0.238	3157 (26.074 %)	3157 (26.074 %)	1	<0.001
65–74	8561 (52.393 %)	8902 (63.713 %)	<0.001	0.238	7419 (61.274 %)	7419 (61.274 %)	1	<0.001
≥ 75	1757 (10.753 %)	1734 (12.411 %)	<0.001	0.238	1532 (12.653 %)	1532 (12.653 %)	1	<0.001
Diagnosis year								
2007–2009	2574 (15.753 %)	3677 (26.317 %)	<0.001	0.303	2442 (20.168 %)	2442 (20.168 %)	1	<0.001
2010–2012	5000 (30.6 %)	4598 (32.909 %)	<0.001	0.303	4005 (33.077 %)	4005 (33.077 %)	1	<0.001
2013–2016	8766 (53.647 %)	5697 (40.774 %)	<0.001	0.303	5661 (46.754 %)	5661 (46.754 %)	1	<0.001
Charlson comorbidity index								
0, 1	5655 (34.608 %)	5296 (37.904 %)	<0.001	0.073	4357 (35.984 %)	4357 (35.984 %)	1	<0.001
2, 3	6268 (38.36 %)	5233 (37.453 %)	<0.001	0.073	4556 (37.628 %)	4556 (37.628 %)	1	<0.001
≥ 4	4417 (27.032 %)	3443 (24.642 %)	<0.001	0.073	3195 (26.388 %)	3195 (26.388 %)	1	<0.001
Hospital type								
Teaching hospital	7448 (45.581 %)	7240 (51.818 %)	<0.001	0.125	5922 (48.91 %)	5922 (48.91 %)	1	<0.001
Nonteaching hospital	8892 (54.419 %)	6732 (48.182 %)	<0.001	0.125	6186 (51.09 %)	6186 (51.09 %)	1	<0.001
Hospital location								
Capital area	6976 (42.693 %)	5768 (41.283 %)	0.014	0.029	5230 (43.195 %)	5230 (43.195 %)	1	<0.001
Provincial area	9364 (57.307 %)	8204 (58.717 %)	0.014	0.029	6878 (56.805 %)	6878 (56.805 %)	1	<0.001

SMD, standardized mean difference.

usage ($p < 0.001$), salvage RT ($p < 0.001$), readmission (<1 year) ($p < 0.001$), and incontinence (<1 year) ($p < 0.001$) significantly impacted costs, rather than the surgical approach (Table 3).

4. Discussion

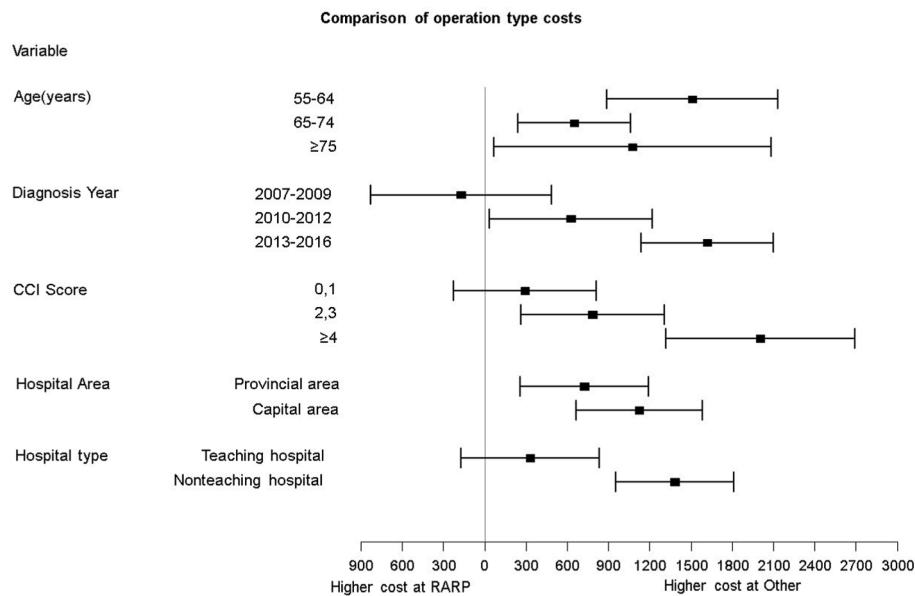
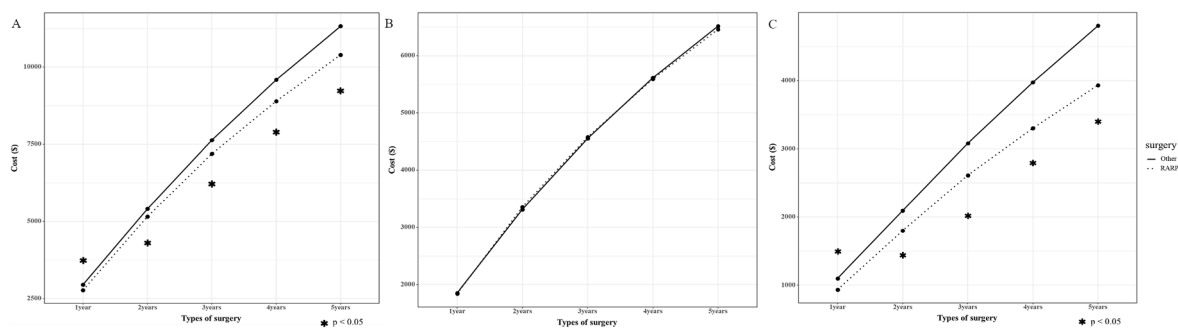
Prostate cancer is increasingly becoming a significant concern in South Korea, following global trends. Among men, the prostate is expected to become the most common primary site for cancer.¹³ As the demand for prostate cancer surgery rises, RARP is becoming the most frequently used technique in South Korea.⁵ Robotic surgery is generally more expensive than other surgical methods.¹⁴ We compared the clinical outcomes and medical costs of the RARP

group and the other surgery group on a national level. We found that the postoperative costs of robotic surgery were lower than those of other surgical methods, primarily due to differences in outpatient expenses. Multivariate analysis of patients with high costs revealed that those requiring ADT or salvage RT due to recurrence, those needing medications for incontinence, and those with prolonged postoperative recovery, as indicated by longer hospital stays and the need for transfusions, incurred higher expenses. Although our multivariate analysis did not identify the surgical approach itself as an independent predictor of postoperative cost, the univariate trends and subgroup patterns consistently favored RARP, particularly among patients with higher comorbidity burdens and in specific hospital settings. This

Table 2
Operative outcomes.

	Robot (n = 12,108)	Other (n = 12,108)	p-value
Operating time (>4 h)	6281	5852	<0.001
Transfusion	935	4742	<0.001
Length of hospital stay (days)	8.963 (± 4.979)	11.879 (± 6.271)	<0.001
ADT usage	2796	3133	<0.001
Salvage RT	1697	1566	0.014
Readmission (<3 months)	869	1227	<0.001
Readmission (<1 year)	1282	1724	<0.001
Readmission (Overall)	2410	3030	<0.001
Incontinence (<3 months)	6293	6502	<0.001
Incontinence (<1 year)	7273	7588	<0.001
Incontinence (overall)	8464	8919	<0.001
Overall mortality (<3 months)	58	48	0.381
Overall mortality (<1 year)	192	212	0.341
Overall mortality (Overall)	1396	1761	<0.001

ADT, androgen deprivation therapy; RT, radiation therapy.

**Fig. 2.** Comparison of postoperative costs by surgical approach.**Fig. 3.** Mean cumulative costs per patient by surgical approach: (a) total costs, (b) hospitalization costs, (c) outpatient costs.

suggests that the cost advantages of RARP may emerge indirectly, through reduced complications and faster recovery, rather than from the surgical approach alone.

This study demonstrates that RARP is associated with better clinical outcomes, such as reduced transfusion rates and shorter hospital stays, compared to other surgical methods. These findings

are consistent with previous studies, such as those by Parsons et al.⁸ and Carbonara et al.,⁹ which reported similar advantages of RARP over open and laparoscopic approaches. The reduced transfusion rates in RARP can be attributed to the enhanced three-dimensional visualization and magnification provided by the robotic system, which allows for better identification of anatomical

Table 3
Univariate and multivariate regression analyses of 5-year postoperative costs.

Variable	Case n (%)	Postoperative cost (\$) Mean (SD)	Univariate p-value	Multivariate p-value
Surgical approach			<0.001	0.754
RARP	12,108 (50 %)	10392.94894 ($\pm$ 12380.061)		
Other	12,108 (50 %)	11322.19124 ($\pm$ 13527.969)		
Operating time (>4 h)	12,133 (50.1 %)	10906.580 ($\pm$ 12664.402)	0.622	–
Length of hospital stay (continuous)	24,216 (100 %)	10857.570 ($\pm$ 12976.993)	<0.001	<0.001
Transfusion	5677 (23.4 %)	12389.392 ($\pm$ 14720.963)	<0.001	0.002
ADT usage	5929 (24.5 %)	16627.375 ($\pm$ 14197.332)	<0.001	<0.001
Salvage RT	3263 (13.5 %)	21015.245 ($\pm$ 12967.881)	<0.001	<0.001
Readmission (<1 year)	3006 (12.4 %)	15291.544 ($\pm$ 15898.275)	<0.001	<0.001
Incontinence (<1 year)	14,861 (61.4 %)	11159.689 ($\pm$ 12970.399)	<0.001	<0.001
Overall mortality (<1 year)	404 (1.7 %)	11166.325 ($\pm$ 12947.902)	0.839	–

structures. Additionally, features such as tremor filtration and increased intra-abdominal pressure help minimize blood loss. The shorter hospital stays can be linked to the minimally invasive nature of RARP, resulting in faster recovery times and fewer postoperative complications.

The benefits of RARP extend beyond the immediate postoperative period.¹⁵ In terms of functional outcomes, RARP patients experienced lower rates of incontinence and fewer complications compared to those undergoing other surgical methods. This aligns with findings from a randomized controlled trial conducted in Australia by Yaxley et al.,¹⁶ which compared robotic and open prostatectomy and found improved early continence in the RARP group. The precise dissection and nerve-sparing techniques possible with robotic surgery likely contribute to these improved functional outcomes. Additionally, multiple studies have shown that patients undergoing RARP achieve better continence outcomes in both the short and long term. For instance, Bartoletti et al.¹⁷ reported that intraoperative techniques such as bladder neck preservation and posterior musculofascial reconstruction during RARP significantly improve urinary continence recovery. These techniques help maintain the anatomical structures that support the urinary sphincter, thereby reducing the incidence of postoperative incontinence.

Incontinence can have a significant financial impact, not just because of the direct costs of incontinence treatment. Billions of dollars are spent on incontinence care in institutional settings and among community-dwelling individuals. Patients with incontinence are more likely to use expensive paraprofessional services, purchase medical equipment, and incur higher public costs for home care.¹⁸ Furthermore, incontinence, which is negatively associated with self-efficacy and quality of life, can be a major barrier to social activities, entertainment, and physical recreation. Reducing complications, particularly incontinence, is crucial not only for lowering postoperative costs but also for enhancing patients' quality of life.¹⁹ The combination of these advanced surgical techniques and the inherent benefits of robotic technology contributes to the superior continence outcomes observed in RARP patients. These findings underscore the importance of employing precise surgical methods to enhance patient recovery and quality of life postoperatively.

Oncologic outcomes are another crucial aspect of prostate cancer treatment. Our study found a meaningful difference in overall mortality between RARP and other surgical methods during the entire follow-up period, with RARP showing better survival rates. Although overall mortality within 3 months was 58 for the RARP group compared to 48 for the other surgery group ($p = 0.381$), and overall mortality within 1 year was 192 for the RARP group compared to 212 for the other surgery group ($p = 0.341$), the overall mortality for the entire follow-up period was 1396 for the RARP group compared to 1761 for the other

surgery group ($p < 0.001$). In addition to survival rates, we used ADT usage and salvage RT as indicators of cancer recurrence. The ADT usage was 2796 in the RARP group compared to 3133 in the other surgery group ($p < 0.001$), and salvage RT usage was 1697 in the RARP group compared to 1566 in the other surgery group ($p = 0.014$). These findings suggest that, in our cohort, the RARP group had a lower recurrence rate than the other surgery group. However, this observation may be influenced by unadjusted tumor characteristics or patient conditions present in the nationwide data. This contrasts with several meta-analyses, such as those by Hu et al.¹⁷ and Bolenz et al.,¹² which reported no significant difference in cancer recurrence or overall survival. The superior oncologic outcomes in our study suggest that the advantages of RARP may extend to long-term cancer control, possibly due to reduced postoperative complications and faster recovery times, which can significantly impact patients' quality of life and overall treatment experience.

The observed influence of hospital type and geographic location on cost highlights a potential disparity in healthcare resource allocation and surgical expertise. Teaching hospitals and capital-area institutions may achieve greater efficiency in RARP delivery due to higher procedure volumes, multidisciplinary teams, and streamlined postoperative care pathways. These findings underscore the need for strategies to ensure equitable access to high-quality surgical care across all regions and facility types. The significant impact of hospital type and location on postoperative costs underscores the need for equitable access to high-quality surgical care. Patients treated in teaching hospitals and those in the capital area had lower postoperative costs, likely due to differences in healthcare resources, provider experience, and access to advanced surgical technologies.²⁰ Ensuring that all patients, regardless of geographic location or hospital type, have access to advanced surgical techniques like RARP is essential for optimizing clinical outcomes and reducing healthcare costs.

Research on the medical costs of RARP and other surgical approaches has been conducted in several countries. In the Netherlands, a study compared the medical costs incurred by RARP and laparoscopic radical prostatectomy (LRP) over a 7-year period. The study found that RARP was more cost-effective, primarily due to lower costs associated with urinary incontinence treatment after surgery.²¹ In France, an annual nationwide analysis of costs and postoperative outcomes compared RARP, LRP, and open radical prostatectomy (ORP). Although the initial surgical cost for RARP was higher, the study concluded that RARP had better short-term performance, leading to faster recovery and reduced overall financial burden.²⁰ In the United States, a comparison of 1-year healthcare costs and usage between RARP and ORP revealed that while RARP incurred higher costs during hospitalization, post-discharge costs were significantly lower, effectively offsetting the initial expenses.²²

This study has several strengths. First, the use of a large, nationally representative cohort provides a robust dataset that enhances the generalizability of the findings. Second, the application of PSM helps to minimize confounding factors, ensuring a more accurate comparison between RARP and other surgical methods. Third, the comprehensive analysis of postoperative costs over a 5-year period offers valuable insights into the long-term economic impact of these surgical approaches.

However, there are several limitations to this study. The lack of detailed clinical data, such as preoperative Gleason scores and PSA levels, limits our ability to fully account for disease severity. Similar limitations were noted in studies by Hu et al.⁴ and Bolenz et al.,¹² where the absence of detailed clinical information posed challenges in interpreting outcomes. Additionally, our reliance on claims data may introduce inaccuracies related to coding practices, which could affect the validity of the findings. The inability to capture out-of-pocket expenses and non-covered medical costs further constrains the economic analysis. In particular, because the non-reimbursable initial cost of robotic surgery was excluded, our analysis focused solely on postoperative costs. As a result, we could not evaluate the full economic profile that incorporates both initial and long-term expenditures. Future studies should integrate these components to enable a comprehensive cost-effectiveness assessment. Furthermore, there is a potential selection bias in our study, as patients who underwent RARP may have had less advanced disease or better overall health, which could influence the observed outcomes. In addition, hospital type and geographic location—both shown in our results to affect postoperative costs—may reflect broader disparities in healthcare access and resource allocation. Such structural factors could not be fully adjusted for in our analysis and may have confounded the cost comparisons between surgical approaches.

Despite these limitations, this study provides significant evidence that RARP is associated with better perioperative, functional, and oncologic outcomes compared to other surgical methods for prostate cancer. Future research should aim to incorporate more detailed clinical data and explore the impact of RARP on long-term oncologic outcomes. Additionally, studies should consider a broader range of economic factors, including indirect costs and quality-of-life measures, to provide a more comprehensive evaluation of the benefits and costs of RARP.

5. Conclusion

In prostate cancer patients, RARP demonstrated favorable outcomes in terms of transfusion rates, hospital stay duration, readmission rates, incontinence, and ADT usage. While the surgical approach itself was not an independent predictor of postoperative costs in multivariate analysis, these favorable outcomes likely contribute indirectly to cost reduction through fewer complications and improved functional recovery. Achieving good functional and oncologic outcomes remains essential for lowering postoperative costs, as effective management of incontinence and minimizing the need for ADT and salvage RT can substantially reduce the financial burden on healthcare systems and improve patient quality of life. Given that the initial, non-reimbursable cost of robotic surgery was not included in this analysis, our findings cannot fully establish the overall cost-effectiveness of RARP. Nevertheless, the observed trends suggest that RARP may become economically advantageous over time, particularly in settings with optimized perioperative care. Future studies incorporating both initial and long-term costs, as well as detailed clinical and patient-reported outcomes, are warranted to comprehensively evaluate the value of RARP in prostate cancer management.

Authors' contributions

Study concept and design: Se Young Choi.

Acquisition of data: Se Young Choi and Yoonjong Bae.

Analysis and interpretation of data: Se Young Choi, Donghyun Lee, and Jae Hun Shim.

Drafting of the manuscript: Donghyun Lee and Jae Hun Shim.

Critical revision of the manuscript for important intellectual content: Se Young Choi.

Obtaining funding: Se Young Choi.

Supervision: Se Young Choi.

Data sharing

The raw sequencing data are not publicly available as these compromise patient consent and ethical regulations in South Korea.

Declaration of generative AI and AI-assisted technologies in the writing process

There is no need to add a statement.

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Conflicts of interest

The authors declare no conflicts of interest.

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None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.asjsur.2025.12.165>.

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