



# Changes in Patterns of Radical Prostatectomy due to Diffusion of Robotic Surgical System: A Nationwide Study Using Health Insurance Claims Data

Jungmi Chae\*, Yeonmi Choi\*, and Su-Jin Cho

Health Insurance Review & Assessment Service, Wonju, Korea.

**Purpose:** This study analyzed the changes in the number of surgeries and surgical patterns due to the adoption and diffusion of new medical technology while focusing on radical prostatectomy.

**Materials and Methods:** Medical equipment status report data and the National Health Insurance claims data from 2007 to 2019 were used. A total of 62798 radical prostatectomies from 135 medical facilities were analyzed. Radical prostatectomy was classified into open radical prostatectomy (ORP), laparoscopic radical prostatectomy (LRP), and robot-assisted laparoscopic radical prostatectomy (RARP) using the fee schedule codes. A linear mixed model was used to determine whether the adoption of a robotic surgical system had an effect on the number of surgeries and surgical patterns after adjusting for medical characteristics.

**Results:** The number of radical prostatectomies performed in Korea increased from 1756 in 2007 to 8475 in 2019. During this period, the proportion of RARP in total surgery increased from 17.5% to 74.3%. The mean number of surgeries at medical facilities adopting the robotic surgical system was 128.3, which was higher compared to 18.5 cases in medical facilities that did not adopt it. The adoption of a robotic surgical system increased the number of radical prostatectomy surgeries by 12.1 cases and the RARP share by 47.2% in a linear mixed model.

**Conclusion:** The adoption and diffusion of robotic surgical systems in Korea increased the number of surgeries as well as the share of robotic surgery. It is necessary to manage a technology that is widely used in a state where its clinical effectiveness is uncertain.

**Key Words:** Robotic surgical procedures, prostatectomy, prostatic neoplasms

## INTRODUCTION

Robotic surgery has been widely applied in the field of prostate cancer surgery since it was first performed at Severance Hospital in July 2005.<sup>1,2</sup> Radical prostatectomy has been reported to account for more than 78% of robotic surgeries in Korea.<sup>2</sup>

**Received:** July 16, 2021 **Revised:** September 23, 2021

**Accepted:** September 29, 2021

**Corresponding author:** Su-Jin Cho, PhD, Health Insurance Review & Assessment Service, 60 Hyeoksins-ro, Wonju 26465, Korea.

Tel: 82-33-739-1665, Fax: 82-33-811-7604, E-mail: nereus00@hira.or.kr

\*Jungmi Chae and Yeonmi Choi contributed equally to this work.

•The authors have no potential conflicts of interest to disclose.

© Copyright: Yonsei University College of Medicine 2021

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<https://creativecommons.org/licenses/by-nc/4.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

The robotic surgical system was approved by the Ministry of Food and Drug Safety in 2005, and the National Health Insurance (NHI) registered robotic surgery as a non-covered item in July 2006. Health technology should meet the standards of safety, effectiveness, and cost-effectiveness to be compensated by the NHI; however, robotic surgery lacked economic evidence at that time.

Since 2006, several attempts have been made to cover the cost of robotic surgery through the NHI. In July 2013, robotic surgery was reviewed to strengthen NHI coverage for major diseases such as cancers and cardio-cerebrovascular diseases. It was then reconsidered to reduce patient co-payments when the government announced a policy that would include all non-covered items by the NHI in July 2017. However, robotic surgery has not been covered by the NHI until 2021. There were three reasons for robotic surgery not being covered by the NHI. First, there was insufficient evidence on clinical safety and ef-

fectiveness compared to open or laparoscopic surgery, except for some indications.<sup>1,3</sup> Second, robotic surgery could be a burden on the NHI budget, since it is more expensive than open or laparoscopic surgery. Open and laparoscopic surgery costed 1.43 and 3.63 million KRW, respectively, whereas robotic surgery costed 12.7 million KRW at that time.<sup>4</sup> Low cost-effectiveness is a barrier to NHI coverage. Third, healthcare providers opposed the coverage of robotic surgery as the price of surgery could be lowered.

Nevertheless, robotic surgery has established itself as a major surgery for radical prostatectomy. In the United States, robotic surgery accounted for more than 60% of radical prostatectomies, and was conducted more frequently than open surgery in 2009.<sup>5</sup> In Korea, robotic surgery was performed similarly to open and laparoscopic surgery in the early 2010s.<sup>6,7</sup>

The treatment patterns of prostate cancer in the early 2010s were analyzed using the Korean health insurance claims data.<sup>7,8</sup> Sixty-one medical facilities had 92 robotic surgical systems in 2019. Compared to 2014, the number of robotic surgical systems has doubled; but since then, no studies have been conducted on the number of robotic surgeries or surgical patterns in prostate cancer. Therefore, this study aimed to analyze the number of radical prostatectomy surgeries and surgical patterns between 2007 and 2019. In addition, this study analyzed how the number of surgeries and surgical patterns changed when a medical facility adopted the robotic surgical system. The results of this study will clarify how existing medical technologies are replaced by the adoption and diffusion of new medical technologies.

## MATERIALS AND METHODS

### Source

The medical equipment status report data and NHI claim data from 2007 to 2019 were used in the Health Insurance Review and Assessment Service. The status of the robotic surgery system and radical prostatectomy were identified using medical equipment status report data and NHI claims data, respectively. Radical prostatectomy was defined by the fee schedule code for surgery, anesthesia, and malignant tumor examination for a claim in which the primary disease was a malignant neoplasm of the prostate (C61).

Between 2007 and 2019, 62 medical facilities had a robotic surgical system, of which two medical facilities did not perform radical prostatectomy. A total of 139 medical facilities underwent radical prostatectomy, and 62804 surgeries were performed over 13 years. During the analysis period, six surgeries were performed at four hospital-level medical facilities. Due to the low number of surgeries per facility, statistical estimation of hospital-level medical facilities was difficult; hence, it was excluded from the final analysis. A total of 62798 surgeries from 135 medical facilities above the general hospital level were

included in the final analysis. As of 2019, 8475 surgeries from 102 facilities were analyzed.

### Constructing data

The number of surgeries and surgical patterns were analyzed by merging the radical prostatectomy claims data with the robotic surgical system data and constructed by the medical facility in a year. Medical facilities had a maximum of 13 data points from 2007 to 2019.

Radical prostatectomy was classified into open radical prostatectomy (ORP), laparoscopic radical prostatectomy (LRP), and robot-assisted laparoscopic radical prostatectomy (RARP) according to the surgical method. Four groups of fee schedule codes were used to classify surgical methods: surgery (R3950, R3960), laparoscopic medical material (N0031001), anesthesia (L1211), and malignant tumor test (C5500, C5503, C5504, C5505, C5506, C5507, C5508, C5918, C5919, C5605, C5606, and C5607). Cases claiming four groups of fee schedule codes were defined as LRPs, and those without laparoscopic medical material codes were classified as ORPs. Medical facilities cannot charge the NHI with the RARP fee code, as they are not covered by the NHI. However, hospitalization fees, anesthesia fees, and examination expenses incurred during RARP are billed to the NHI. Therefore, a claim in which no prostate operation codes (R3940, R3950, R3960, R3975, R3976, and R3977) were included was defined as RARP, but anesthesia and malignant tumor examination fee codes were confirmed.

### Analysis

The number of radical prostatectomies and surgical patterns by year were presented using descriptive statistics. The chi-square test was used to determine whether the adoption of the robotic surgical system differed according to medical facility characteristics in 2019. The t-test or analysis of variance was used to test the differences in the number of radical prostatectomies and surgical patterns according to the medical facility characteristics. Finally, a linear mixed model was used to analyze the effect of adopting a robotic surgical system on the number of surgeries and surgical patterns between 2007 and 2019. The number of surgeries and the share of each surgery in the medical facilities were used as dependent variables. We analyzed whether the adoption of robotic surgical systems had an effect on each dependent variable after adjusting for the year and characteristics of the medical facility. A random coefficient regression model in which the year and intercept were treated as random effects was used, since the error terms of the same medical facilities correlated with each other. Data construction and statistical analysis were performed using SAS Enterprise Guide 7.1.

This study was reviewed by the Institutional Review Board of Health Insurance Review and Assessment Service and was given an exempt determination (no. 2018-032-001).

## RESULTS

### Number of radical prostatectomy and surgical patterns between 2007 and 2019

Table 1 summarizes the number of radical prostatectomies performed between 2007 and 2019. In 2007, 72 medical facilities performed radical prostatectomy. The number of medical facilities that performed radical prostatectomy increased until 2019, with a temporary decrease in the years 2012, 2015, and 2018. In 2019, 102 medical facilities performed radical prostatectomies. The number of radical prostatectomies increased from 1756 in 2007 to 8475 in 2019, with an annual average increase of 14.0%. Regarding the surgical method, RARP in-

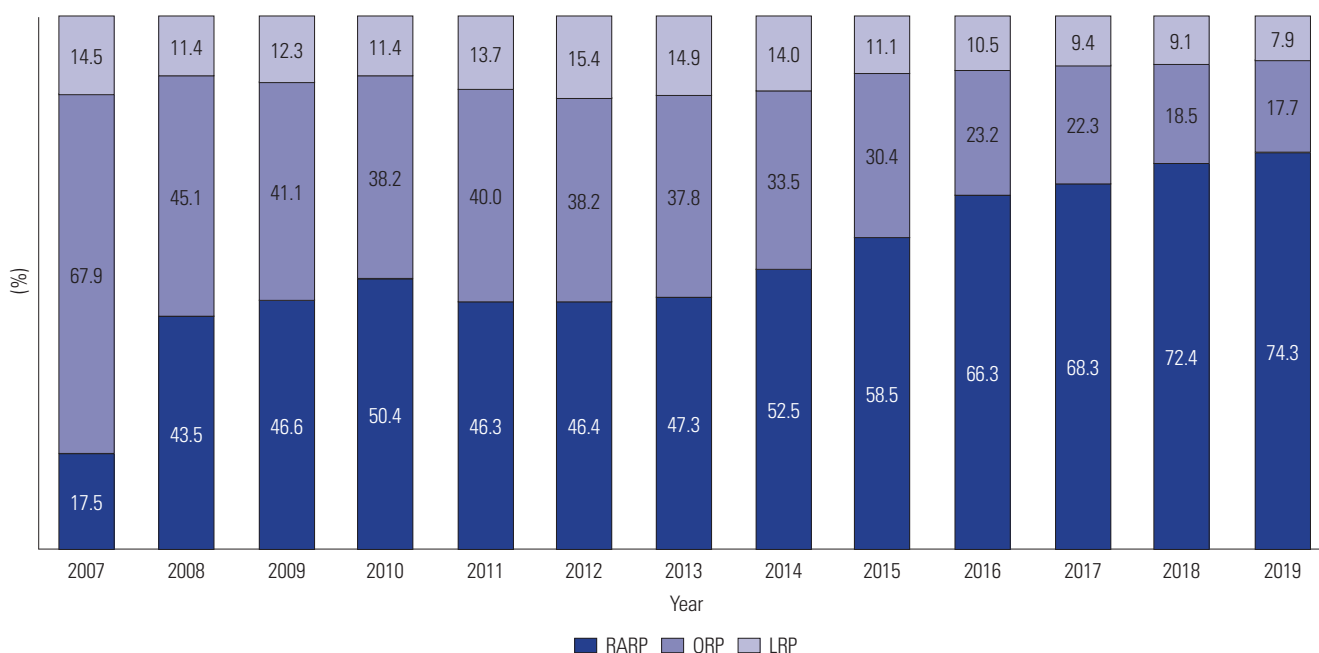
creased by 28.6% annually, while RLP and ORP increased by 8.4% and 1.9%, respectively.

The share of ORP was high at the beginning of the introduction of the robotic surgical system; but as the number of RARP surgeries surged in 2008, RARP had the largest share in 2009. The share of RARP in 2007 increased from 17.5% to 74.3% in 2019. There was also a period when the market share of RARP decreased slightly from 2011 to 2013. However, as the number of robotic surgical systems increased in 2014, the share of RARP also increased. On the other hand, ORP, which accounted for 67.9% in 2007, decreased to 17.7% in 2019. The share of LRP also decreased from 14.5% in 2007 to 7.9% in 2019 (Fig. 1).

**Table 1.** Number of Medical Facilities Operating Radical Prostatectomy and Number of Surgical Cases in 2007–2019

Year	Medical facilities operating radical prostatectomy		Radical prostatectomy			
	Total	Adopting robotic surgical system	Total	ORP	LRP	RARP
2007	72	8	1756	1193 (67.9)	255 (14.5)	308 (17.5)
2008	79	13	2557	1152 (45.1)	292 (11.4)	1113 (43.5)
2009	88	19	3448	1416 (41.1)	425 (12.3)	1607 (46.6)
2010	94	25	3673	1404 (38.2)	419 (11.4)	1850 (50.4)
2011	97	30	4421	1768 (40.0)	605 (13.7)	2048 (46.3)
2012	90	30	4618	1764 (38.2)	712 (15.4)	2142 (46.4)
2013	98	34	4730	1787 (37.8)	705 (14.9)	2238 (47.3)
2014	103	36	4713	1581 (33.5)	660 (14.0)	2472 (52.5)
2015	99	44	4798	1460 (30.4)	531 (11.1)	2807 (58.5)
2016	100	47	5825	1351 (23.2)	610 (10.5)	3864 (66.3)
2017	101	52	6460	1441 (22.3)	605 (9.4)	4414 (68.3)
2018	99	57	7324	1354 (18.5)	666 (9.1)	5304 (72.4)
2019	102	60	8475	1504 (17.7)	672 (7.9)	6299 (74.3)

ORP, open radical prostatectomy; LRP, laparoscopic radical prostatectomy; RARP, robot-assisted laparoscopic radical prostatectomy.



**Fig. 1.** Patterns of radical prostatectomy in 2007–2019. ORP, open radical prostatectomy; LRP, laparoscopic radical prostatectomy; RARP, robot-assisted laparoscopic radical prostatectomy.

**Robotic surgical system adoption rate, number of surgeries, and surgical pattern of radical prostatectomy by medical facility characteristics in 2019**

Among medical facilities that performed radical prostatectomy in 2019, 60 (58.8%) medical facilities had a robotic surgical system. Tertiary hospitals and medical facilities with more than 900 beds had the highest rate of adoption of robotic surgical system, which was statistically significant as a result of the chi-square test. The adoption rate of the robotic surgical system in teaching hospitals was higher than that in non-teaching hospitals, and it was statistically significant. However, the adoption rates of medical facilities in metropolitan areas and private medical facilities were not statistically significantly higher (Table 2).

Medical facilities performed 83.1 surgeries per facility in 2019. The share by surgical method was 35.6% for ORP, 23.1% for LRP, and 41.3% for RARP. The mean number of surgeries at medical facilities with robotic surgical system was 128.3, with RARP accounting for 70.2%. On the other hand, the number of surgeries at medical facilities not adopting the robotic surgical system was 18.5 cases, which was significantly lower than that of medical facilities adopting it. The ORP and LRP shares were similar at the 50% level.

Based on the results of the t-test or ANOVA, there were statistically significant differences in the number of surgeries and surgical patterns by medical facility characteristics, except for

the variables of whether medical facilities are located in metropolitan areas or not and whether they are public or not (Table 3).

**Table 2.** Distribution of Medical Facilities Operating Prostatectomy according to the Possession of Robotic Surgical System and Characteristics of Medical Facilities in 2019

	Adopting robotic surgical system		p value
	Yes (n=60)	No (n=42)	
Classification of hospital			<0.001
Tertiary	35 (85.4)	6 (14.6)	
General	25 (41.0)	36 (59.0)	
Number of beds			<0.001
≥900	24 (92.3)	2 (7.7)	
600–899	26 (60.5)	17 (39.5)	
300–599	8 (29.6)	19 (70.4)	
<300	2 (33.3)	4 (66.7)	
Metropolitan area			0.216
Yes	36 (64.3)	20 (35.7)	
No	24 (52.2)	22 (47.8)	
Teaching			<0.001
Yes	52 (74.3)	18 (25.7)	
No	8 (25.0)	24 (75.0)	
Public			0.892
Yes	15 (57.7)	11 (42.3)	
No	45 (59.2)	31 (40.8)	

**Table 3.** Number of Surgeries and Patterns of Radical Prostatectomy according to Characteristics of Medical Facilities in 2019

	Number of surgeries		Share of surgeries (%)					
	Mean±SD	p value	ORP		LRP		RARP	
			Mean±SD	p value	Mean±SD	p value	Mean±SD	p value
Total	83.1±164.7	-	35.6±40.4	-	23.1±38.0	-	41.3±43.0	-
Adopting robotic surgical system		<0.001		0.002		<0.001		-
Yes	128.3±202.0		25.6±33.2		4.2±11.7		70.2±33.1	
No	18.5±28.2		49.9±45.7		50.1±45.7		-	
Classification of medical facilities		<0.001		0.025		0.005		<0.001
Tertiary	159.0±236.9		24.7±33.6		10.4±25.0		64.9±37.4	
General	32.1±40.6		42.9±43.2		31.7±42.8		25.4±39.2	
Number of beds		<0.001		0.005		0.019		<0.001
≥900	209.2±283.5		16.1±19.0		7.6±20.7		76.3±32.2	
600–899	52.5±49.8		39.7±39.1		22.1±36.6		38.2±40.4	
300–599	26.7±44.8		39.1±44.3		39.9±46.7		21.0±39.0	
<300	10.0±15.3		74.8±42.0		22.4±40.4		2.8±7.0	
Metropolitan area		0.085		0.301		0.051		0.462
Yes	108.5±213.8		39.4±41.7		16.5±32.3		44.1±43.5	
No	52.1±56.9		31.1±38.8		31.2±42.9		37.8±42.5	
Teaching		0.933		0.509		<0.001		<0.001
Yes	84.0±144.2		33.8±39.9		12.8±28.6		53.4±42.2	
No	81.0±205.1		39.5±42.0		45.7±46.0		14.8±31.6	
Public		0.499		0.909		0.718		0.833
Yes	102.1±122.4		34.8±39.9		25.5±39.5		39.7±42.0	
No	76.6±177.1		35.9±40.9		22.3±37.7		41.8±43.5	

ORP, open radical prostatectomy; LRP, laparoscopic radical prostatectomy; RARP, robot-assisted laparoscopic radical prostatectomy; SD, standard deviation.

### Effect of the adoption of robotic surgical system on the number of surgeries and surgical pattern of radical prostatectomy

The adoption of a robotic surgical system in medical facilities from 2007 to 2019 increased the number of radical prostatectomies as a result of linear mixed model analysis. Even after adjusting for both year and medical facility characteristics, the adoption of robotic surgical system significantly increased the number of surgeries by 12.1 cases (Table 4).

The adoption of a robotic surgical system also affected the surgical pattern of radical prostatectomy as a result of the linear mixed model analysis. It increased the share of RARP by 47.2%, while that of ORP and LRP decreased by 27.7% and 16.3%, respectively. It was found to reduce the share of ORP more than the LRP (Table 4).

## DISCUSSION

This study confirmed that the number of radical prostatectomies increased by 14.0% annually, and the share of RARP increased from 17.5% in 2017 to 74.3% in 2019 due to the diffusion of the robotic surgical system based on the analysis of health insurance claims data from 2007 to 2019. The introduction of the robotic surgical system increased the number of surgeries at medical facilities by 76.5 on average, and RARP replaced ORP and LRP.

The increase in the number of radical prostatectomies over the past 13 years was due to an increase in the incidence of prostate cancer in Korea. Prostate cancer was the 4th most common

cancer in men in 2018, accounting for 11.5%.<sup>9</sup> Although the prevalence rate of prostate cancer in Korea is lower than that in the United States, which accounts for 21% of male cancers, the incidence of prostate cancer in the United States is declining. In contrast, the prevalence of prostate cancer continues to increase in Korea.<sup>9,10</sup> Prostate cancer occurred in 7.6 cases of the 100000 population in 2000; but in 2018, it increased by approximately 4.2 times to 32.0 cases per 100000 population.<sup>9</sup> The increase in surgery as the main treatment method for prostate cancer may also be the cause for the increase in the number of radical prostatectomies, along with an increase in cases of prostate cancer. There are three main treatment methods for prostate cancer: surgery, radiation therapy, and hormone therapy, including androgen deprivation therapy (ADT). The share of surgery increased from 22.4% in 2003 to 45.5% in 2013, while the share of ADT decreased from 60.3% to 45.3%.<sup>8</sup> The proportion of patients who underwent surgery only increased from 23.5% in 2005 to 39.4% in 2014, and the share of patients increased to 47.9% in 2014 after including patients who received surgery in combination with other treatments.<sup>7</sup>

In Korea, after the first RARP was performed in 2005, the share of RARP increased to 17.5% within 2 years. The RARP shares in 2005 and 2006 were reported to be 2.6% and 5.6%, respectively, which increased to 17.5% in 2007.<sup>7</sup> According to the innovation adoption curve, innovative technology spreads in an S-shape; and the adopters are categorized as innovators, early adopters, early majority, late majority, and laggards over the adoption period.<sup>11,12</sup> The period when innovative technology spreads from the early adopters to the early majority and when innovative technology occupies 15%–20% is called the tipping

**Table 4.** Changes in Number of Cases and Patterns of Radical Prostatectomy after Adopting Robotic Surgical System in 2007–2019

	Number of surgeries		Share of surgeries (%)					
			ORP		LRP		RARP	
	C.E	p value	C.E	p value	C.E	p value	C.E	p value
Intercept	13.083	0.351	82.775	<0.001	30.143	0.005	-10.912	0.023
Year	3.106	<0.001	-2.094	<0.001	0.886	0.052	1.112	<0.001
Adopting robotic surgical system								
Yes vs. No	12.124	<0.001	-27.682	<0.001	-16.286	<0.001	47.240	<0.001
Classification of medical facilities								
Tertiary vs. General	-0.979	0.876	-2.425	0.768	0.527	0.946	1.025	0.735
Number of beds								
≥900 vs. <300	6.598	0.658	-10.060	0.467	-0.849	0.948	7.669	0.160
600–899 vs. <300	-1.396	0.922	0.003	1.000	-0.375	0.974	1.335	0.787
300–599 vs. <300	-5.693	0.686	-11.204	0.320	6.056	0.568	5.055	0.280
Metropolitan area								
Yes vs. No	8.302	0.081	10.836	0.057	-12.891	0.016	2.043	0.342
Teaching								
Yes vs. No	-7.438	0.218	-4.299	0.552	-3.108	0.648	4.650	0.088
Public								
Yes vs. No	4.315	0.442	3.887	0.561	-2.666	0.672	-1.820	0.471

C.E, coefficient estimate; ORP, open radical prostatectomy; LRP, laparoscopic radical prostatectomy; RARP, robot-assisted laparoscopic radical prostatectomy.

point. When an innovation reaches a tipping point, it can no longer stop spreading and begins to expand rapidly.<sup>12</sup> According to the innovation adoption curve, RARP reached a tipping point of 17.5% within 2 years after its introduction, and its share in 2008 increased significantly to 43.5%.

In the United States, after the first RARP was performed in 2000, it reached a tipping point between 2007 and 2008, and the share of RARP increased significantly to 59.6% in 2009.<sup>5</sup> Although RARP in Korea reached the tipping point earlier compared to the United States, RARP's share could reach 58.5% after 8 years. RARP quickly reached the tipping point because, in the early days of RARP introduction, the four largest hospitals that performed more than 300 radical prostatectomies per year started RARP. Afterwards, the spread of robotic surgery, including RARP, had stalled as it was reported that the safety and effectiveness of robotic surgery was uncertain in a study conducted to determine whether RARP was covered by health insurance.<sup>1</sup> There was also a case in which a celebrity died after robotic surgery.<sup>13</sup> However, the share of RARP increased again in 2013 and 2017, as robotic surgery was reviewed again as a part of strengthening the NHI coverage.

While the number of radical prostatectomies is increasing every year, it was confirmed that the introduction of the robotic surgical system increased the number of surgeries in medical facilities even after the year was adjusted. It is possible that patients in medical facilities that did not introduce the robotic surgical system moved to the medical facilities that introduced the system. In addition, the patient probably chose minimally invasive RARP instead of radiation or hormone therapy. However, we cannot rule out the possibility that the number of surgeries through RARP had increased in medical facilities adopting robotic surgical systems. The introduction of new medical technology can increase medical utilization as medical suppliers can induce their usage.<sup>14,15</sup> Although the number of prostate cancer cases in the United States has declined, the increase in the number of RARP surgeries has been explained by supplier-induced medical utilization.<sup>16</sup> In contrast to the United States, the number of prostate cancer patients in Korea is increasing and requires more surgery than before. It is highly likely that medical facilities increased the number of surgeries with RARP, which can perform more surgeries in a limited time and leave a large profit per surgery.<sup>17</sup>

In the present study, RARP replaced ORP and LRP in medical facilities that adopted a robotic surgical system. Similarly, in the United States and Australia, RARP replaced ORP or LRP and became the most frequently performed procedure.<sup>18,19</sup> RARP may have replaced ORP and LRP to increase the profits of medical facilities in the same way that the number of surgeries has increased.<sup>16</sup> However, clinical evidence of RARP and improved convenience for surgeons cannot be ignored. There is much evidence that robotic surgery for prostate cancer is clinically safer and more effective than open or laparoscopic surgery.<sup>3</sup> The oncological outcomes of RARP and ORP are similar,

and the incidence of complications and urinary incontinence is low.<sup>3,20</sup> Compared with LRP, there was no difference in the conversion rate to ORP, and the risk of damage, such as peripheral organ damage and blood transfusion, was low.<sup>3</sup> Moreover, although RARP lacks high-quality evidence as a random clinical trial, clinical evidence is accumulating that it has advantages similar to LRP in terms of non-invasiveness. However, the surgery time is shorter than that of LRP, and it does not take a long time to overcome the learning curve; therefore, surgeons may prefer RARP.<sup>21-23</sup>

In Korea, robotic surgery is used not only for prostate cancer, but also for thyroid, colorectal, and various gynecological cancers.<sup>1,24</sup> Although there is insufficient evidence that the safety and effectiveness of robotic surgery are superior to those of laparoscopic surgery, the number of surgeries is gradually increasing. This situation is the same in the United States, and there are concerns about side effects due to its use in situations where clinical evidence is uncertain.<sup>25</sup> Since the benefits of health insurance in Korea apply to many citizens, if clinical evidence and economic feasibility are judged to be insufficient, a higher co-payment rate is applied. Medical use was monitored, and data on side effects were collected from medical facilities. However, since robotic surgery is not covered by the NHI, side effects are not monitored despite the disclosure of prices for each medical institution. In the absence of monitoring for side effects, robotic surgery has reached a point where it has already been applied to many people. It is necessary to reimburse payments to reduce the burden on patients, as many people undergo robotic surgeries. It is also necessary to continuously discuss which compensation method to choose and to be covered by NHI under the circumstance that a new technology is less cost-effective than the existing one.

This study presented the situations of robotic surgery over 13 years by analyzing Korea's national data while focusing on radical prostatectomy. However, this study had two limitations. First, since RARP is not covered by the NHI, it is possible that it was underestimated compared to other procedures that covered by the NHI. Second, administrative data analysis is useful for understanding the overall trend of medical use, but it is not possible to determine whether ORP, LRP, and RARP are applied to patients with different clinical characteristics and surgical outcomes. Large-scale studies with well-designed clinical outcomes are needed to discuss health insurance reimbursement.

This study analyzed the number and pattern of radical prostatectomy in which robotic surgery was most frequently applied using the NHI claims data from 2007 to 2019. Robotic surgery reached a tipping point where medical technology spread in earnest in 2007 and has replaced existing medical technologies such as open and laparoscopic surgery. In addition, the adoption of robotic surgical systems in medical facilities increased the number of surgeries and the share of robotic surgery. Although its safety and effectiveness are uncertain and

cost-effectiveness is low, robotic surgery has already been widely used in clinical settings. The management of such new health technologies in the healthcare system should be discussed.

## ACKNOWLEDGEMENTS

This study was funded by the Health Insurance Review & Assessment Service.

## AUTHOR CONTRIBUTIONS

**Conceptualization:** Su-Jin Cho. **Data curation:** Jungmi Chae and Yeonmi Choi. **Formal analysis:** Jungmi Chae. **Funding acquisition:** all authors. **Investigation:** Jungmi Chae. **Methodology:** Su-Jin Cho. **Project administration:** Yeonmi Choi. **Resources:** all authors. **Software:** Jungmi Chae. **Supervision:** Su-Jin Cho. **Validation:** Su-Jin Cho. **Visualization:** Yeonmi Choi. **Writing—original draft:** Su-Jin Cho and Yeonmi Choi. **Writing—review & editing:** all authors. **Approval of final manuscript:** all authors.

## ORCID iDs

Jungmi Chae <https://orcid.org/0000-0003-2634-1738>  
 Yeonmi Choi <https://orcid.org/0000-0002-0120-2646>  
 Su-Jin Cho <https://orcid.org/0000-0003-1642-867X>

## REFERENCES

1. Shin CM, Lee YJ, Seo HS, Jang BY, Park JE, Son HJ, et al. Health technology assessment of robot surgeries by reflecting the national status of Korea. Seoul: National Evidence-based Healthcare Collaborating Agency; 2011.
2. Seo IY. Urologic robotic surgery in Korea: past and present. *Korean J Urol* 2015;56:546-52.
3. Lee SH, Kim JH, Hwang JS, Choi JE, Shin EH, Lee NR, et al. Clinical safety and effectiveness of robotic surgery. Seoul: National Evidence-based Healthcare Collaborating Agency; 2013.
4. Yoon JE, Park DA, Ahn JH, Oh SH, Lee NR, Kim JM, et al. Economic evaluation of robotic surgery in prostate cancer in Korea. Seoul: National Evidence-based Healthcare Collaborating Agency; 2015.
5. Parsons JK, Messer K, Palazzi K, Stroup SP, Chang D. Diffusion of surgical innovations, patient safety, and minimally invasive radical prostatectomy. *JAMA Surg* 2014;149:845-51.
6. Ko WJ, Han HH, Kim KH, Han JH, Kim DW, Ko EY. Analysis of the current status of robotic surgery for the urinary system in South Korea. Goyang: National Health Insurance Service Ilsan Hospital; 2014.
7. Kang HW, Yun SJ, Chung JI, Choi H, Kim JH, Yu HS, et al. National practice patterns and direct medical costs for prostate cancer in Korea across a 10 year period: a nationwide population-based study using a national health insurance database. *BMC Health Serv Res* 2019;19:408.
8. Park J, Suh B, Shin DW, Hong JH, Ahn H. Changing patterns of primary treatment in Korean men with prostate cancer over 10 years: a nationwide population based study. *Cancer Res Treat* 2016;48:899-906.
9. Korea Central Cancer Registry, National Cancer Center. Annual report of cancer statistics in Korea in 2018. Sejong: Ministry of Health and Welfare; 2014.
10. Siegel RL, Miller KD, Jemal A. Cancer statistics, 2020. *CA Cancer J Clin* 2020;70:7-30.
11. Rogers EM, Singhal A, Quinlan MM. Diffusion of innovations. In: Stacks DW, Salwen MB, Eichhorn KC, editors. An integrated approach to communication theory and research. 3rd ed. New York: Routledge; 2019. p.418-34.
12. Berwick DM. Disseminating innovations in health care. *JAMA* 2003;289:1969-75.
13. Seo EK. Death of actress Park Joo-Ah... Sense of medical accident [Internet] [accessed on 2021 July 15]. Available at: <http://www.docdocdoc.co.kr/news/articleView.html?idxno=100935>.
14. Wennberg JE. Time to tackle unwarranted variations in practice. *BMJ* 2011;342:687-90.
15. Kalkan A. Diffusion, implementation and consequences of new health technology: the cases of biological drugs for rheumatoid arthritis and the Swedish national guidelines. Linköping: Linköping University; 2015.
16. Makarov DV, Yu JB, Desai RA, Penson DF, Gross CP. The association between diffusion of the surgical robot and radical prostatectomy rates. *Med Care* 2011;49:333-9.
17. Lowrance WT, Eastham JA, Savage C, Maschino AC, Laudone VP, Dechet CB, et al. Contemporary open and robotic radical prostatectomy practice patterns among urologists in the United States. *J Urol* 2012;187:2087-92.
18. Basto M, Sathianathan N, Te Marvelde L, Ryan S, Goad J, Lawrentschuk N, et al. Patterns-of-care and health economic analysis of robot-assisted radical prostatectomy in the Australian public health system. *BJU Int* 2016;117:930-9.
19. Oberlin DT, Flum AS, Lai JD, Meeks JJ. The effect of minimally invasive prostatectomy on practice patterns of American urologists. *Urol Oncol* 2016;34:255.e1-5.
20. Seo HJ, Lee NR, Son SK, Kim DK, Rha KH, Lee SH. Comparison of robot-assisted radical prostatectomy and open radical prostatectomy outcomes: a systematic review and meta-analysis. *Yonsei Med J* 2016;57:1165-77.
21. Lee YS, Han WK, Yang SC, Rha KH. Robot-assisted laparoscopic radical prostatectomy. *Korean J Urol* 2006;47:206-10.
22. Ban JH, Ko YH, Kang SH, Park HS, Cheon J. Learning curve with robotic-assisted laparoscopic radical prostatectomy: a prospective study. *Korean J Urol* 2009;50:140-7.
23. Sung NS, Kim SH. Current status and future prospect of robotic surgery in Korea. *J Minim Invasive Surg* 2014;17:55-61.
24. Koh DH, Jang WS, Park JW, Ham WS, Han WK, Rha KH, et al. Efficacy and safety of robotic procedures performed using the da Vinci robotic surgical system at a single institute in Korea: experience with 10000 cases. *Yonsei Med J* 2018;59:975-81.
25. Sheetz KH, Claflin J, Dimick JB. Trends in the adoption of robotic surgery for common surgical procedures. *JAMA Netw Open* 2020;3:e1918911.