

Urologic robotic surgery in Korea: Past and present

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Since 2005 when the da Vinci surgical system was approved as a medical device by the Korean Ministry of Health and Welfare, 51 systems have been installed in 40 institutions as of May 2015. Although robotic surgery is not covered by the national health insurance service in Korea, it has been used in several urologic fields as a less invasive surgery. Since the first robotic-assisted laparoscopic radical prostatectomy in 2005, partial nephrectomy, radical cystectomy, pyeloplasty, and other urologic surgeries have been performed. The following should be considered to extend the indications for robotic surgery: training systems including accreditation, operative outcomes from follow-up results, and cost-effectiveness. In this review, the history and current status of robotic surgeries in Korea are presented.

Keywords: Korea; Nephrectomy; Prostatectomy; Robotics

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HISTORY OF UROLOGIC ROBOTIC SURGERY IN KOREA

1. Introduction

The da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA, USA) is the most widely used robotic surgical system. It was approved by the Food and Drug Administration (FDA) of the United States in 2000, and the company received FDA clearance for use of the system in prostate surgery in 2001 [1]. In Korea, the surgical system was approved as a medical device in July 2005 by the Korean Ministry of Health and Welfare. The first launching of the da Vinci Standard surgical system in Korea was undertaken at the Severance Hospital of Yonsei University in July 2005. Subsequently, the da Vinci S surgical system was introduced in July 2007. The da Vinci Si and da Vinci Xi surgical systems were introduced in January 2010 and December 2014, respectively. Up to May 2015, a total of 51 da

Vinci surgical systems had been installed in 40 institutions in Korea. Most of the systems are in Seoul and Gyeonggi provinces (n=34), followed by Gyeongsang (n=9), Jeolla (n=3), Chungcheong (n=2), Gangwon (n=2), and Jeju (n=1) provinces.

2. Initial clinical reports

Before launching the da Vinci surgical system in Korea, Sung performed 5 cases of robot-assisted laparoscopic radical prostatectomy (RALRP), which were undertaken Dong-A University Hospital, Korea and Singapore General Hospital, Singapore in 2004, and the operative results were presented by Kong et al. [2]. In Korea, the first urologic robotic surgery was performed by Rha in July 2005, and Lee et al. [3] presented it as an initial report. It was a RALRP using the da Vinci Standard surgical system in the Severance Hospital. The first case of robot-assisted laparoscopic partial nephrectomy (RALPN) was completed in September 2006

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[4]. Park et al. [4] from Severance Hospital reported 11 cases of RALPN for small renal masses. They performed tumor excision and intracorporeal suturing with the robotic surgical system. Park et al. [5] also performed the first case of robot-assisted laparoscopic radical cystectomy (RALRC) in March 2007. They reported four cases of RALRC in patients with invasive bladder cancer. Ileal conduit urinary diversion was made by the extracorporeal technique. Robot-assisted laparoscopic radical nephrectomy and robot-assisted laparoscopic radical nephroureterectomy with bladder cuff excision were first performed in 2007 [6]. These were also performed at Severance Hospital. The first case of robot-assisted laparoscopic pyeloplasty (RALPP) was done in August 2007. Kim et al. [7] from Ulsan University presented five cases of RALPP, showing the technical feasibility of the procedure. Other robotic surgeries including distal ureterectomy and ureteral reimplantation [8], partial cystectomy for urachal disease [9], adrenalectomy [10], and retroperitoneal lymph node dissection [11] also began to be performed in the Korean urologic field.

The number of urologic robotic surgeries has increased dramatically since 2008. In 2014, more than 3,400 cases of urologic robotic surgery were performed in Korea. There were 2,658 cases of RALRP, 478 cases of RALPN, 53 cases of RALRC, and 29 cases of RALPP (Fig. 1).

3. Education and training

Several workshops and symposiums for robotic surgeries have taken place. Initially, these focused on techniques and surgical tips. The Korean Urological Association (KUA) has tried to teach robotic surgery and improve its technique. The first symposium on robotic prostatectomy took place in

April 2006. Of note, Vipul R. Patel (GRI, Florida Hospital, University of Central Florida, Orlando, FL, USA) performed an athermal nerve-sparing robotic radical prostatectomy live at a 2009 KUA surgical workshop. The Korean Endourological Society (KES) also made an effort to increase the use of robotic surgery. Thomas W. Jarrett (The Johns Hopkins Hospital, Baltimore, MD, USA) presented a special lecture on robotic surgery at the 2005 KES annual meeting. Nowadays, it is not difficult to learn robotic surgery, which is also found on the urologist board examination.

Two robotic training centers were established. The Severance Robot and Minimally Invasive Surgery Center and the Asan Medical Center Robot Training Center were opened in June 2009 and July 2013, respectively. The centers have trained medical doctors including main operators and fellows, nurses, and coordinators. There are several training programs including basic training using a porcine model and wet lab and advanced training courses. The training centers focus on general surgery, cardiothoracic surgery, gynecology, and urology. The Severance center had carried out 313 basic training sessions and the Asan Medical Center had carried out 139 training sessions by June 2015. Of note, the Severance Center presented an advanced training course using a cadaver.

Robotic surgeries are increasing in number and are becoming more popular as a result of these efforts in Korea. However, there are no clinical guidelines or limitations for the use of the da Vinci surgical system. Also, the KUA and KES have not yet established a certification system for robotic surgeons.

ROBOT-ASSISTED LAPAROSCOPIC RADICAL PROSTATECTOMY

Several surgeries to treat localized prostate cancer have been performed in Korea. Koh and Cho [12] reported the first retroperitoneal radical prostatectomy (RRP) in 1989. However, open radical prostatectomy has associated surgical morbidity and complications including blood loss [13]. To prevent the surgical invasiveness and complications, laparoscopic surgery was started. In Korea, Jang et al. [14] presented the first laparoscopic radical prostatectomy (LRP) in 2002. However, it was difficult in this laparoscopic surgery to manipulate the instruments in the deep pelvic cavity with a two-dimensional view, and the surgery had a steep learning curve. Robotic technology with the da Vinci surgical system decreases the learning curve for laparoscopic prostatectomy [15]. The da Vinci surgical system allows more delicate and free motion through wristed instruments and a magnified

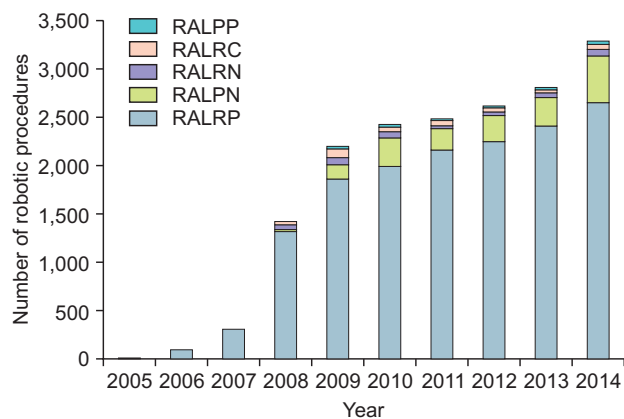


Fig. 1. Number of robotic surgeries in Korea (data from Intuitive Surgical Korea Ltd.). RALPP, robot-assisted laparoscopic pyeloplasty; RALRC, robot-assisted laparoscopic radical cystectomy; RALRN, robot-assisted laparoscopic radical nephrectomy; RALPN, robot-assisted laparoscopic partial nephrectomy; RALRP, robot-assisted laparoscopic radical prostatectomy.

three-dimensional view.

The da Vinci surgical system received FDA clearance in prostate surgery, and Binder and Kramer [16] published the first series of RALRP completed in 10 patients in 2001. In Korea, the first RALRP was performed in July, 2005 [3]. The da Vinci Standard surgical system was used for a 69-year-old man with prostate cancer. The operation time was 420 minutes, including 80 minutes of robot set-up time including port placement. Total amount of blood loss was 200 mL, and the urethral Foley catheter was removed postoperative day 14. The initial conclusion was of the benefits of enhanced precision and dexterity in the pelvic cavity. Because installation of the da Vinci surgical system dramatically increased in 2008, the number of RALRP procedures has also increased (Fig. 2). As their experience accumulated, Rha [17] revealed several techniques of RALRP, such as the conventional nerve-sparing technique, endopelvic fascia-saving technique, ultradissection technique, and extraperitoneal approach. Seo et al. [18] investigated the learning curve and outcomes of RALRP. They reported that the robotic console time decreased after the first 10 cases and reached under 3 hours after 75 cases in 100 cases of RALRP. Although the time for several steps decreased with experience, the time for vesicourethral anastomosis did not decrease dramatically.

Prostate cancer patients undergoing radical prostatectomy are interested in operative complications including voiding and erectile function as well as oncologic outcome. In comparative studies with RALRP (60 cases) and LRP (60 cases), Porpiglia et al. [19] showed that RALRP (60 cases) provided better functional outcomes concerning continence and potency. Rates of erection recovery after the nerve-

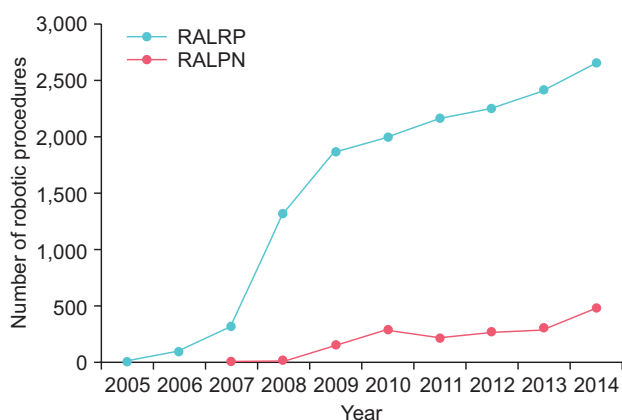


Fig. 2. Increasing situations of robot-assisted laparoscopic radical prostatectomy and partial nephrectomy in Korea (data from Intuitive Surgical Korea Ltd.). RALPP, robot-assisted laparoscopic pyeloplasty; RALPN, robot-assisted laparoscopic partial nephrectomy.

sparing technique were 80.0% in the RALRP group and 54.2% in the LRP group. Ploussard et al. [20] presented results from 1,377 cases of LRP and 1,009 cases of RALRP, which were performed by use of an extraperitoneal approach. Shorter operative times and hospital stays and lower mean blood loss were reported in the RALRP group compared with the LRP group. Although the surgical approach did not affect continence recovery, robot assistance was independently predictive for potency recovery. Survival analyses showed equal oncologic control between the two groups. In data from 19,064 men who underwent RALRP and LRP, Robertson et al. [21] showed that RALRP had a lower rate of major intraoperative complications and positive surgical margins. There were no significant differences in urinary incontinence and insufficient data on sexual dysfunction. Vora et al. [22] reported oncologic outcomes from 1,011 cases of RALRP and 415 cases of open RRP in a multicenter study. Although the overall positive-margin rate was 47.1% in the RALRP group, the rate decreased significantly with increasing surgeon experience. The biochemical recurrence rate also increased. The results suggested better oncologic outcomes with a higher volume of RALRP procedures.

In a Korean study, Cho et al. [23] compared their experience with 120 cases of radical prostatectomy by laparoscopy versus robot-assisted. The RALRP group showed better results for operative time, estimated blood loss, hospital stay, and bladder catheterization duration. The trifecta (positive surgical margin, potency, and continence at postoperative 12 months) results were nonsignificantly better in the RALRP group (23.3%, 30.1%, 6.7%) than in the LRP group (38.3%, 31.7%, 28.3%). However, the authors worried about the economic hurdles to RALRP. Ryu et al. [24] reported operative outcomes in 524 cases of RALRP compared with 341 cases of RRP. RALRP was associated with a shorter duration of hospital stay (7.9 days vs. 10.1 days) and bladder catheterization (6.2 days vs. 7.5 days) than RRP. Major complications of Clavien grade III–IV (7.6% vs. 3.4%), postoperative urinary retention (7.0% vs. 2.7%), postoperative wound repair (4.1% vs. 0.2%), and urinary extravasation on cystogram (10.0% vs. 2.1%) were more common in the RRP group than in the RALRP group.

ROBOT-ASSISTED PARTIAL NEPHRECTOMY

The standard treatment for localized renal cancer has shifted from radical nephrectomy to partial nephrectomy because partial nephrectomy preserves renal function. Laparoscopic partial nephrectomy (LPN) has less operative morbidity than open partial nephrectomy (OPN), with

similar oncologic results [25]. In a Korean multicenter study, operative outcomes from 417 cases of LPN and 345 cases of OPN were compared [26]. Blood loss was greater in the OPN group than in the LPN group (418 mL vs. 293 mL). The glomerular filtration rate at the last available follow-up was similarly decreased in both groups. Five-year local recurrence-free survival was 96% after LPN and 94% after OPN. Although LPN can be performed without renal arterial clamping in selected cases, it is a technically difficult procedure with a steep learning curve [27].

With the development of robotic technique, RALPN has been presented. Now RALPN may offer a wider range of indications, better operative outcomes, and lower perioperative morbidity than LPN. RALPN is likely to become the new standard treatment as a less-invasive surgery for localized renal cancer. Khalifeh et al. [28] operative results of 500 RALPN and LPN cases. The robot helped them to accomplish the trifecta, which was defined as a combination of warm ischemia time less than 25 minutes, negative surgical margins, and no perioperative complications.

RALPN was started in September 2006 in Korea. Park et al. [4] have reported 11 cases of RALPN. The mean operative time in their series was 179.5 minutes and the mean warm ischemia time was 30.4 minutes. There were no major complications or positive surgical margins. Seo et al. [29] compared the operative outcomes of 13 cases of RALPN and 14 cases of LPN. Although these were initial experiences, there were no significant differences in operation times including robotic console time and laparoscopic time (153.2 minutes in the RALPN group vs. 117.5 minutes in the LPN group). The mean warm ischemic time in the two groups was 35.3 minutes and 36.4 minutes, and the surgical margins were negative in all cases.

Subsequently, the number of RALPN procedures has increased (Fig. 2). Jang et al. [30] compared the perioperative outcomes of RALPN (89 cases) and LPN (38 cases) for complex renal tumors. They reported no significant differences in warm ischemic time, blood loss, intraoperative complications, or operation time between the RALPN group and the LPN group. RALPN had the advantage of healthy parenchymal preservation because differences in surgical margin width between the RALPN and LPN groups remained statistically significant (0.4 cm vs. 0.6 cm). RALPN with zero ischemia is possible with increasing experience. Shin et al. [31] presented operative results for seven cases of RALPN that were done by using a three-dimensional reconstruction protocol. They selectively clamped the tertiary arterial branches supplying the tumor before resection.

Total operation time was 185 minutes, and estimated blood loss was 300 mL. Choi et al. [32] analyzed 23 studies and 2,240 patients who underwent RALPN and LPN. In their meta-analysis, RALPN was associated with more favorable renal function (estimated glomerular filtration rate), shorter hospital stay, shorter warm ischemic time, and lower radical conversion rate. However, the number of clinical studies of RALPN for operative and oncologic outcomes is small in Korea. If RALPN is widely accepted as a standard therapy for localized renal cancer, well-designed randomized clinical trials with long-term follow-up are necessary.

ROBOT-ASSISTED LAPAROSCOPIC RADICAL CYSTECTOMY

Radical cystectomy is the most effective and standard treatment for invasive bladder cancer. The procedure requires a long operation time, however, and is associated with operative morbidity, which is true for both open and laparoscopic surgeries. RALRC has been reported, and intracorporeal construction of the urinary diversion has also been described [33]. The RALRC procedure was reported to result in lower blood loss and shorter hospital stay compared with open surgery.

In Korea, Park et al. [5] also performed the first case of RALRC in March 2007. They reported four cases of RALRC with ileal conduit urinary diversion for patients with invasive bladder cancer. The mean operation time was 355 minutes, and the estimated blood loss was 550 mL. The mean duration of hospital stay was 12 days. Kang et al. [34] presented 21 cases of RALRC, which included 13 cases of ileal conduit urinary diversion and eight cases of orthotopic neobladder. They also tried extended pelvic lymph node dissection. The mean operation time was 515.5 minutes, and the estimated blood loss was 346.8 mL. Kwon et al. [35] also presented 17 cases of RALRC with extracorporeal urinary diversion (13 ileal conduits and four orthotopic neobladders). The mean operation time was 379.1 minutes, and the mean estimated blood loss was 210.5 mL. The mean hospital stay was 20.7 days. Kang et al. [36] presented a developed technique of RALRC with complete intracorporeal urinary diversion. They made three cases of ileal conduit and one case of orthotopic neobladder with intracorporeal method. These clinical experiences indicate that RLRC is a feasible procedure with less blood loss and early recovery. However, wound dehiscence, anastomotic leakage, urinary tract obstruction, mechanical obstruction, and thromboembolism also occurred as major complications [37].

RALRC is still in progress, and the true benefits

of robotic surgery are not yet known. With improved technology, especially improved suturing and stapling devices, the procedure will most likely move to a more intracorporeal approach. Such improvements will also result in shorter operation times [1,38].

ROBOT-ASSISTED LAPAROSCOPIC PYELOPLASTY

Pyeloplasty is one of the gold standard treatments for ureteropelvic junction obstruction (UPJO) [39]. Laparoscopic pyeloplasty has been performed as a less invasive surgery, and its success rates are equivalent to those of open surgery. Long-term follow-up results also support laparoscopic pyeloplasty as the standard treatment for ureteropelvic junction obstruction [40]. However, intracorporeal suture has remained a technical drawback. The da Vinci surgical system can address this difficulty.

The first case of robotic-assisted laparoscopic pyeloplasty (RALPP) was done in August 2007. Kim et al. [7] presented five cases of RALPP and reported the technical feasibility of the procedure. Mean operative time was 276 minutes, and the average length of the postoperative hospital stay was 4.2 days. There were no intraoperative complications or transfusion. The success rate was 80%. The robot allows the surgeon to overcome technical difficulties with intracorporeal suturing, which is the rate-limiting step in laparoscopic pyeloplasty [41]. However, there are few published articles for RALPP, most of which are just small series. For this reason, it may be asked whether RALPP is a standard surgery for UPJO.

OTHER TYPES OF ROBOTIC SURGERY

Other types of robotic surgery for urological disease have also been performed in Korea. All of these presentations are on initial and challenging robotic surgeries. These show that robotic surgeries are technically feasible and cosmetically favorable. However, we should consider cost-effectiveness and long-term follow-up results.

Park et al. [6] performed robot-assisted laparoscopic nephroureterectomy with a bladder cuff excision. The operative times were 320 and 241 minutes, respectively, for the two patients. The estimated blood loss was 40 and 200 mL. Kang et al. [8] performed robotic distal ureterectomy with bladder cuff excision, and ureteroneocystostomy for a patient with a distal ureteral tumor. The operation time was 207 minutes, and the estimated blood loss was 30 mL. Kim et al. [9] reported their initial experience with robot-

assisted laparoscopic partial cystectomy in urachal diseases. In four patients, the mean operative time was 198 minutes, and the mean estimated blood loss was 155 mL. You et al. [10] presented 15 patients who underwent robot-assisted laparoscopic adrenalectomy and compared the results with the operative results of laparoscopic adrenalectomy. The mean operation time was longer in the robotic group (208.2 minutes) than in the laparoscopic group (181.1 minutes). Lee et al. [11] presented a case of robot-assisted retroperitoneal lymph node dissection, which was performed in an 18-year-old man with a stage IIIb mixed germ cell tumor. The total operative time was 420 minutes. There were no postoperative complications. They removed 20 lymph nodes.

ROBOT-ASSISTED LAPAROENDOSCOPIC SINGLE-SITE SURGERY

Laparoendoscopic single-site surgery (LESS) is an innovative technique that may exceed standard laparoscopy and provide a cosmetic advantage [42]. Several urologic surgeries have been performed with LESS, although it is hard to finish. In particular, surgeries requiring suturing and a long operative field are difficult [43,44]. Instrumental developments are needed to overcome the technical difficulty.

The da Vinci surgical system has been adopted and tested for LESS. Initially, Kaouk et al. [45] reported single-port robotic surgeries including radical prostatectomy, pyeloplasty, and radical nephrectomy. These surgeries have also begun to be done in the Korean urologic field. Han et al. [46] reported robot-assisted LESS (R-LESS) partial nephrectomy with a hybrid homemade port for 14 patients with renal cell carcinoma. The mean ischemic time was 30 minutes, and the mean operative time was 233 minutes. Seo et al. [47] also used a hybrid homemade port. They performed bilateral robotic single-site partial nephrectomy for a patient with bilateral renal tumors. The warm ischemic time for the left side was 29 minutes, and the total operation time was 350 minutes. Komninos et al. [48] reported three cases of R-LESS partial nephrectomy, which were performed with the use of the novel da Vinci Single-Site platform. They noticed several drawbacks of the platform, including lack of EndoWrist movements, external collisions, and a limited working space for the assistant. Although R-LESS is feasible, these initial experiences revealed that it needs further developments of technique and instruments and should be applied in limited patients.

CONCLUSIONS

Urologic robotic surgeries using the da Vinci surgical system were started in Korea in 2005. Currently, more than 3,300 cases are performed every year. RALRP and RALPN are common procedures. Their operative results are acceptable. However, there are limitations to robotic surgery in Korea. First, cost-effectiveness should be considered because robotic surgery is not covered by the national health insurance. Also, the cost of acquiring and maintaining the robotic system is significantly high. All laparoscopic and open surgeries are covered by the insurance system. Second, guidelines for the use of the da Vinci surgical system and an accreditation system are needed for safety. Such measures are important to prevent possible complications and in the case of academic debate or lawsuit. Finally, effort is needed to expand the indications for and utility of robotic surgery. Clinical trials should be continued. Robotic single-port surgery is a promising example.

CONFLICTS OF INTEREST

The author has nothing to disclose.

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