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# Safety and feasibility of single-port surgery for posterior retroperitoneal adrenalectomy using the da Vinci SP robotic system: a retrospective cohort study

**Byung-Chang Kim[1] · Douk Kwon[1] · Shin Jeong Pak[1] · Jae Won Cho[1] · Won Woong Kim[1] · Tae-Yon Sung[1] · Ki-Wook Chung[1] · Yu-mi Lee[1]**

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## Abstract

**Background** This study demonstrates our experience of single-port robotic posterior retroperitoneal adrenalectomy (RPRA) using the da Vinci SP robot system and evaluates its technical feasibility and surgical outcomes.

**Methods** We conducted a retrospective analysis of 250 RPRAs, including 117 conventional 3-port RPRAs, 103 reduced 2-port RPRAs, and 30 single-port RPRAs. Each RPRA type was compared by analyzing 30 patients in the early phase of surgery.

**Results** All patients who underwent single-port RPRA showed excellent surgical outcomes. Age, sex, BMI, and tumor location site did not significantly differ between the three groups. In the early phase, the size of the adrenal tumor was similar between three groups, and it tended to increase as the number of ports increased ($p < 0.001$). The mean operation time was shorter for patients who underwent single-port RPRA than those who underwent RPRA types ($p < 0.001$). The numeric rating scale score did not significantly differ between the groups on most days. No major complications were observed, and no patients were converted to open surgery or required additional port insertion.

**Conclusion** Single-port RPA using the da Vinci SP robotic system showed the effectiveness of the surgical procedure and improved cosmetic outcomes for patients, while also enabling surgeons to perform operations with greater ease and convenience. Therefore, single-port RPRA could be a good alternative option for the treatment of adrenal tumors in selected situations.

**Keywords** Robotic posterior retroperitoneal adrenalectomy · Reduced port RPRA · Single-port RPRA · Adrenal tumor

Laparoscopic adrenalectomy has emerged as a well-established surgical approach for patients with benign adrenal tumors and is routinely performed worldwide [1, 2]. The most common approaches to adrenalectomy are laparoscopic transperitoneal adrenalectomy (LTA) and posterior retroperitoneoscopic adrenalectomy (PRA). Despite ongoing debate regarding the superior outcome between these two approaches, PRA has several advantages over LTA, including less postoperative pain, shorter operative time, less blood loss, and shorter hospital stay [3]. In addition, PRA is safe and useful in cases with abdominal adhesion because it does not enter the peritoneal cavity through the peritoneum.

As interest and effort in minimally invasive surgery increase, efforts have been made to reduce the number of ports and the incision length [4–6]. Following laparoscopic 3-port adrenalectomy, 2-port or single-port adrenalectomy has been introduced and performed in selected patients. Many studies have already reported the safety and feasibility of these reduced port surgeries [4, 7]; however, the narrow retroperitoneal space of the PRA could be an obstacle to reducing the number of ports.

The robotic surgical system can potentially help overcome this barrier. Robotic adrenalectomy has been successfully performed, and its safety and efficacy have been reported in several studies. With the advantages of the robotic system, such as a 3-dimensional view with a magnified camera and multi-articulated instruments, reducing the number of ports

✉ Yu-mi Lee
niphredil@amc.seoul.kr

[1] Department of Surgery, Asan Medical Center, University of Ulsan College of Medicine, Olympic-Ro 43-Gil 88, Songpa-Gu, Seoul 05505, Republic of Korea

of PRA has become more feasible, and reduced 2-port and single-port PRA using the da Vinci systems are being performed successfully [5, 8–10].

The recently introduced da Vinci SP robotic system has a single-arm structure that facilitates single-port surgery, particularly in a narrow space. Therefore, we suspected the da Vinci SP system would be most suitable for performing single-port PRA. This study investigated the feasibility, safety, and surgical outcomes of single-port PRA using the da Vinci SP robotic system by comparing conventional 3-port and reduced 2-port PRA using the da Vinci Si or Xi system.

## Materials and methods

### Study design and patients

This retrospective study assessed the safety, feasibility, and surgical outcomes of single-port robot PRA (RPRA) performed by three experienced surgeons at a single center. Between January 2016 and December 2022, 279 patients underwent RPRA at Asan Medical Center. Excluding 11 patients with malignant or metastatic lesions and 18 with bilateral lesions, combined surgery, or insufficient data, 250 patients were enrolled in this study. Among them, 117 patients underwent conventional 3-port RPRA, 103 underwent reduced 2-port RPRA, and 30 underwent single-port RPRA (Fig. 1). The initial cohort of 30 consecutive patients who underwent either conventional 3-port or reduced 2-port RPRA were classified as the early-phase groups.

Data on the clinicopathological features of all patients were collected retrospectively, including type of disease, length of hospital stay, site and size of adrenal tumors, mean operation time, numeric rating scale (NRS) pain score, time of analgesics administration, complications, and open conversion in addition to the basic features such as age at the time of surgery, sex, height, weight, and body mass index (BMI).

An analysis was performed across all groups, with an additional between-group comparison of the early phase of conventional 3-port, the early phase of reduced 2-port, and single-port RPRA groups (Fig. 1). This study received approval from the Institutional Review Board at Asan Medical Center (no. 2018-1454), and the requirement for obtaining informed consent from patients was waived given the nature of the study.

### Surgical technique and postoperative management

For robotic retroperitoneal adrenalectomy using the da Vinci robotic system, patients were positioned in a prone jackknife posture with flexion of the hip joint. The pad was positioned around the weight-bearing area to distribute the pressure caused by the weight of the patient.

Conventional 3-port and reduced 2-port RPRA were performed with the da Vinci Xi robotic system, and single-port RPRA was performed with the da Vinci SP robotic system. Reduced 2-port surgery was characterized by the utilization

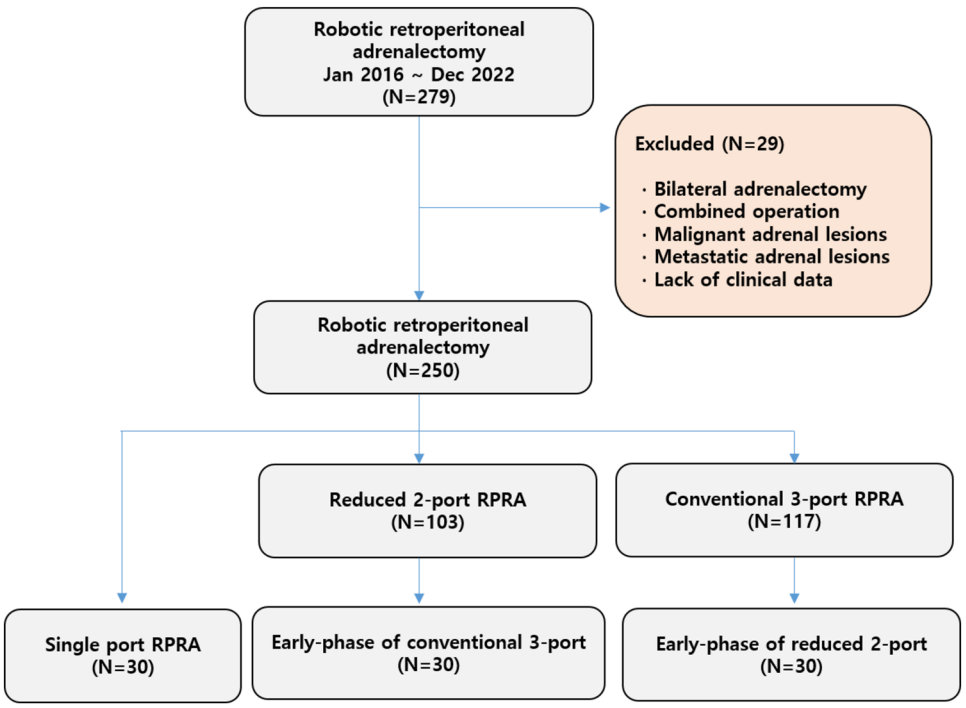


**Fig. 1** Flowchart of the participant selection process and comparison of early-phase RPRA with single-port RPRA. *RPRA* robotic posterior retroperitoneoscopic adrenalectomy

of two port sites, including a multi-glove port and an additional side port. The conventional 3-port RPRA involved making a 1.5-cm incision at the tip of the twelfth rib and a 1.0-cm incision at the tip of the eleventh rib. To prevent subcostal injury, the incisions were made at least 1.0 cm from the tip. A 1 cm incision was also made lateral to the paraspinal muscle. A camera arm was then inserted into the port at the tip of the twelfth rib (Fig. 2A, B). The reduced 2-port RPRA involved making a 2.0- and 1.0-cm incision at the tip of the twelfth and eleventh ribs, respectively, at least 1.0 cm from the tip. A multi-glove port was inserted into the incision at the tip of the twelfth rib, followed by the camera instrument arms (Fig. 2C, D). Single-port RPRA involved making a 3.0-cm transverse incision at the tip of the twelfth rib and inserting the glove port. A single arm was docked to the port and a flexible camera was inserted below the center (Fig. 2E, F). Across all three RPRA techniques, the retroperitoneal space was insufflated with CO2 at a flow rate of 4–6 L per minute, achieving a pressure of 12–15 mmHg.

For postoperative management, oral NSAIDs (acetaminophen and tramadol) were administered twice daily and an intravenous analgesic, ketorolac tromethamine (30 mg), was administered to patients who reported an NRS pain score of 4 or higher upon their request. The NRS pain score was measured 30 min after moving from the operating room to the recovery room and then 4 times at 4-h and 8-h intervals.

### Statistical analysis

All statistical analyses were performed using SPSS version 26 (IBM Corp., Armonk, NY). Continuous variables are presented as mean ± standard deviation along with range and compared using ANOVA, Student's *t* test, and Mann–Whitney *U* tests. Categorical variables are presented as absolute numbers and percentages and compared using the $\chi^2$ or Fisher's exact tests. The associations between phase and duration of surgery were analyzed by scatter plots with Pearson's correlation coefficients and depicted as box plots. Statistical significance was defined as $p$-values $< 0.05$.

## Results

### Baseline characteristics and surgical outcomes

The clinicopathological characteristics and surgical outcomes of the patient groups are presented in Table 1. Age, sex, BMI, and tumor location site did not significantly differ between the three groups.

The size of the adrenal tumor tended to increase as the number of ports increased ($p < 0.001$). Pheochromocytoma and Cushing syndrome were the dominant diseases in the conventional 3-port and reduced 2-port groups (37.6% and 29.9%; 27.2% and 35.0%, respectively), whereas there was a predominance of primary aldosteronism (50.0%) in the single-port group.

Mean operation time was shorter for patients who underwent single-port RPRA than those who underwent 2- and 3-port RPRA ($p < 0.001$). There was no significant difference in NRS pain score between the three groups on the day of surgery and postoperative day 2. On postoperative day 1, the NRS pain score was higher for patients who underwent single-port RPRA than those who underwent other RPRA types ($p < 0.001$); however, there was no difference between the three groups in the number of analgesic administrations.

There were four cases of wound-related surgical complications in the conventional 3-port group and one case of operation bed fluid collection in the reduced 2-port group. No patients included were converted to open surgery.

### Comparison between the three groups during the early phase

Table 2 compares the results of the single-port group with the reduced 2-port and conventional 3-port groups during the early phase. All three groups had adrenal tumors similar in size. The proportion of primary aldosteronism was higher in the early-phase patients of the reduced 2-port and single-port groups. In the conventional 3-port group, the proportion of pheochromocytoma was higher than that of other adrenal diseases. The difference in NRS scores between the three groups was similar to those in Table 1. No early-phase patients had complications or required open conversion.

The mean operation time was the shortest for the single-port surgery group (Fig. 3). Mean operation time was significantly shorter for patients who underwent single-port RPRA than for those who underwent conventional 3-port ($p < 0.001$) or reduced 2-port RPRA ($p < 0.001$). Scatter plot evaluation revealed an operation time ranging from 67 to 260 min in the conventional 3-port group, which decreased as the number of patients increased (Fig. 4). In patients who underwent the reduced 2-port RPRA, the operation time ranged from 65 to 163 min, with a plateau at approximately 100 min. The operation time of the single-port group ranged from 53 to 150 min, with a plateau observed at approximately 80 min.

## Discussion

With the establishment of laparoscopic adrenalectomy as the standard treatment, there have been endeavors to minimize the number of ports and incision length. Several studies reported the successful performance of reduced port or single-port adrenalectomy through the LTA approach [11–14]. LTA has a sizeable abdominal cavity space,

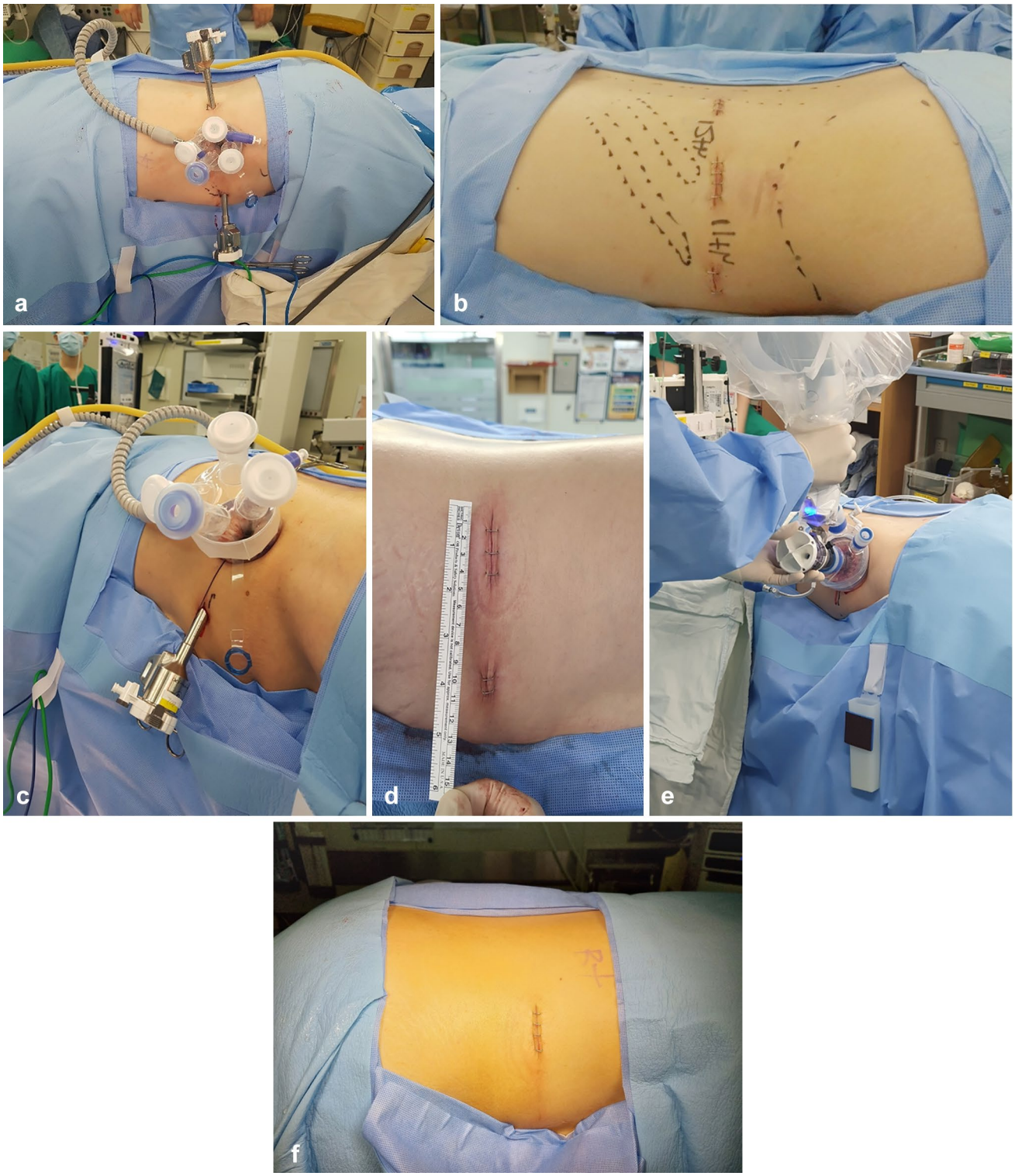


**Fig. 2** Port site and incision locations of conventional 3-port RPRA (**a**, **b**), reduced 2-port RPRA (**c**, **d**), and single-port RPRA (**e**, **f**). *RPRA* robotic posterior retroperitoneoscopic adrenalectomy

allowing for fewer ports. However, recreating this success in the PRA has been challenging owing to the narrow surgical space in the retroperitoneal area around the kidney. During adrenalectomy, severe interference between the instruments poses a challenge in reducing the number of ports. Some studies have reported that surgical outcomes,

**Table 1** Clinicopathological features and surgical outcomes of the three groups of patients who underwent robot posterior retroperitoneal adrenalectomy

| Variables | Single port ($n=30$) | Reduced 2-port ($n=103$) | Conventional 3-port ($n=117$) | $p$-value |
|---|---|---|---|---|
| Age (years) | 48.7 ± 10.4 | 48.5 ± 11.4 | 45.8 ± 11.8 | 0.166 |
| Sex, *n* (%) | | | | 0.627 |
| Male | 12 (40.0) | 32 (31.0) | 41 (35.2) | |
| Female | 18 (60.0) | 71 (69.0) | 76 (64.8) | |
| Adrenal tumor size (cm) | 2.1 ± 1.0 (0.4–5.0) | 3.0 ± 1.4 (0.6–7.0) | 3.9 ± 2.7 (0.8–16.0) | < 0.001 |
| BMI | 24.7 ± 3.9 | 25.2 ± 5.4 | 24.6 ± 3.6 | 0.600 |
| Hospital stays (days) | 4.4 ± 0.8 | 3.8 ± 1.1 | 4.4 ± 1.6 | 0.002 |
| Disease type, *n* (%) | | | | 0.001 |
| Pheochromocytoma | 7 (24.0) | 28 (27.2) | 44 (37.6) | |
| Cushing syndrome | 4 (13.0) | 36 (35.0) | 35 (29.9) | |
| Primary aldosteronism | 15 (50.0) | 25 (24.3) | 16 (13.1) | |
| Other benign diseases | 4 (13.0) | 14 (13.6) | 22 (18.0) | |
| Site of adrenal tumor, *n* (%) | | | | 0.074 |
| Right | 11 (36.7) | 35 (34.0) | 57 (48.7) | |
| Left | 19 (63.3) | 68 (66.0) | 60 (51.3) | |
| Mean operation time (mins) | 80.9 ± 22.1 (53–370) | 99.9 ± 27.6 (57–214) | 134.6 ± 65.8 (50–462) | < 0.001 |
| NRS pain score | | | | |
| Day of surgery | 5.3 ± 1.1 | 5.3 ± 1.4 | 5.5 ± 1.6 | 0.541 |
| POD1 | 3.0 ± 1.5 | 2.2 ± 1.1 | 2.8 ± 1.1 | < 0.001 |
| PDO2 | 1.5 ± 1.1 | 1.4 ± 1.1 | 1.8 ± 1.2 | 0.115 |
| Analgesics (no.) | 4.5 ± 2.7 | 5.7 ± 3.2 | 5.7 ± 3.1 | 0.130 |
| Complications | 0 | 1 | 4 | 0.234 |
| Open conversion | 0 | 0 | 0 | NA |

All results of continuous variables are reported as mean ± SD or mean ± SD (range)

*BMI* body mass index, *NA* not applicable, *no.* number, *NRS* numeric rating scale, *SD* standard deviation, *POD* postoperative day

including operation times and complication rates, were worse with reduced port surgery than conventional multiport approaches [7, 15–18].

The robotic surgical system could help overcome this obstacle. Although the superiority of robotic versus laparoscopic surgery for adrenalectomy remains debated, robotic surgery could offer distinct advantages in reducing the number of ports and the length of the incision in PRA. We have previously reported that PRA can be performed successfully and safely by reducing the number of ports to two using a robotic system [5]. This study investigated whether single-port PRA could also be performed safely using the da Vinci SP robot system.

All patients who underwent single-port RPRA in this study showed excellent surgical outcomes. No additional ports or conversion to open or laparoscopic surgery were required. Furthermore, no surgical-related complications were observed. Complete resection of the adrenal glands without damage was achieved in all patients, resulting in a complete recovery of all patients with adrenal diseases after surgery. Thus, single-port RPRA using the robot SP system was a safe and effective surgical method.

The single-port RPRA using the da Vinci SP system was deemed easier to perform surgeries with than other systems. The multi-arm robotic systems, such as the da Vinci Si or Xi, required outside space to move the multiple arms. Additionally, in the case of PRA, robotic instruments were inserted into a narrow surgical field at a shallow entry angle, leading to many collisions between the multiple arms. Conversely, the SP robotic system had a single arm that used one port, extending to multiple instruments from inside the body of the patient. Therefore, we could facilitate the surgery smoothly without the instruments colliding inside and outside the patient. In addition, the flexible camera could accurately identify the anatomy of an adrenal gland that was located deeper than usual. Thus, the surgery could be easily performed by preventing injuries to important structures, such as the renal vessels. Finally, a single incision of approximately 3.0 cm could provide patients with cosmetic satisfaction.

Since this was the first attempt at applying RPRA using the SP robotic system, patient selection was conducted meticulously. Therefore, the tumor size in the single-port group was smaller than in the other groups. The single-port

**Table 2** Characteristics of the three groups of patients who underwent robot posterior retroperitoneal adrenalectomy during the early phase

| Variables | Single port ($n=30$) | Reduced 2-port ($n=30$) | Conventional 3-port ($n=30$) | $p$-value |
|---|---|---|---|---|
| Age (years) | 48.7 ± 10.4 | 49.4 ± 12.6 | 47.1 ± 11.5 | 0.708 |
| Sex, *n* (%) | | | | 0.436 |
| Male | 12 (40.0) | 8 (26.6) | 7 (23.3) | |
| Female | 18 (60.0) | 22 (73.4) | 23 (76.7) | |
| Adrenal tumor size (cm) | 2.1 ± 1.0 (0.4–5.0) | 2.9 ± 1.5 (1.3–4.4) | 2.9 ± 1.3 (1.0–5.1) | 0.016 |
| BMI | 24.7 ± 3.9 | 24.9 ± 4.5 | 24.2 ± 4.3 | 0.863 |
| Hospital stays (days) | 4.4 ± 0.8 | 3.5 ± 0.9 | 4.9 ± 1.8 | < 0.001 |
| Disease type, *n* (%) | | | | 0.006 |
| Pheochromocytoma | 7 (24.0) | 6 (20.0) | 14 (46.7) | |
| Cushing syndrome | 4 (13.0) | 9 (30.0) | 8 (26.7) | |
| Primary aldosteronism | 15 (50.0) | 9 (30.0) | 7 (23.3) | |
| Other benign diseases | 4 (13.0) | 6 (20.0) | 1 (3.3) | |
| Site of adrenal tumor, *n* (%) | | | | 0.196 |
| Right | 11 (36.7) | 11 (36.6) | 12 (40.0) | |
| Left | 19 (63.3) | 19 (63.4) | 18 (60.0) | |
| Mean operation time (mins) | 80.9 ± 22.1 (53–150) | 105.2 ± 25.4 (65–163) | 127.7 ± 49.3 (67–260) | < 0.001 |
| NRS pain score | | | | |
| Day of surgery | 5.3 ± 1.1 | 5.3 ± 1.2 | 5.8 ± 1.6 | 0.985 |
| POD1 | 3.0 ± 1.5 | 1.9 ± 0.9 | 2.6 ± 1.2 | 0.003 |
| PDO2 | 1.5 ± 1.1 | 1.4 ± 0.8 | 1.7 ± 1.2 | 0.230 |
| Analgesics (no.) | 4.5 ± 2.7 | 4.9 ± 1.9 | 5.1 ± 4.0 | 0.597 |
| Complications | 0 | 0 | 0 | NA |
| Open conversion | 0 | 0 | 0 | NA |

All results of continuous variables are reported as mean ± standard deviation (SD) or mean ± SD (range)

*BMI* body mass index, *NA* not applicable, *no.* number, *NRS* numeric rating scale, *POD* postoperative day

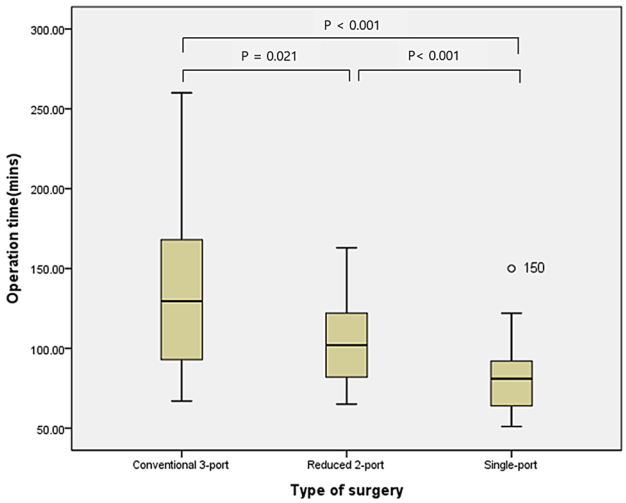


**Fig. 3** Box plots of the overall operation times required for early-phase conventional 3-port and reduced 2-port site robotic posterior retroperitoneal adrenalectomy and single-port site RPRA. *RPRA* robotic posterior retroperitoneoscopic adrenalectomy

group also had a higher proportion of patients with primary hyperaldosteronism, given that these patients were generally considered more suitable for minimally invasive surgery than those with other diseases. However, in the early phases of the reduced 2-port and conventional 3-port groups, similar to the single-port group, tumor size was smaller, and the proportion of primary hyperaldosteronism was higher in the later phase. Therefore, we expect that single-port RPRA using the SP robot system can also be successfully performed on adrenal tumors of larger sizes and various diseases as surgical experience continues to accumulate.

We initially hypothesized that reducing the number of incisions would decrease pain; however, our findings did not support this hypothesis. Notably, one patient who underwent single-port RPRA reported exceptionally severe pain, leading to significantly higher pain scores on the first day in the single-port group. After excluding this patient from the analysis, there was no significant difference in all pain scores based on the number of incisions (data not shown). Our previous study demonstrated that 14 patients who underwent the reduced 2-port RPRA reported less pain than those who underwent the conventional 3-port RPRA [5]. However, expanding our sample to include more patients

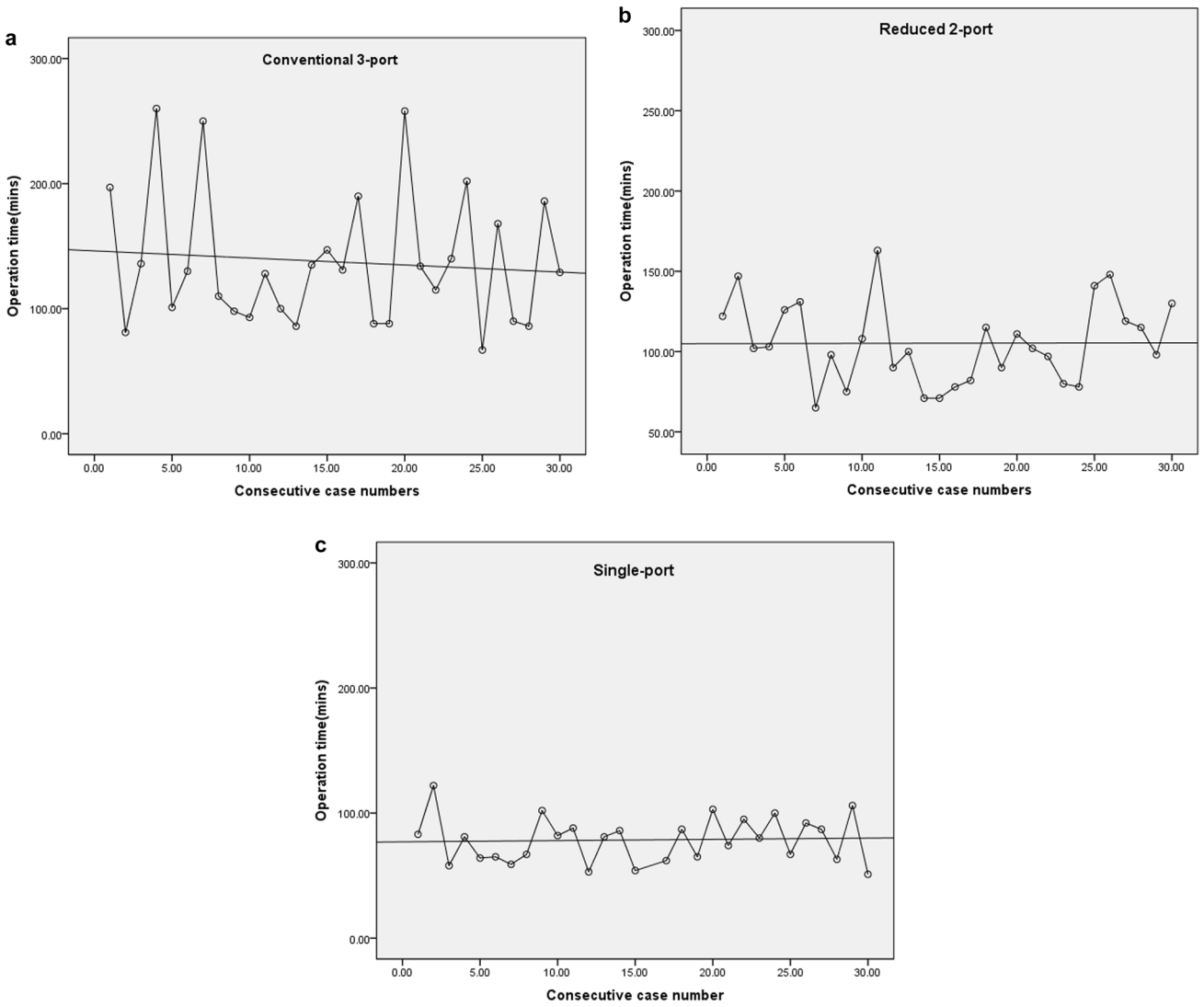


**Fig. 4** Scatter plots of the operation times required for early-phase conventional 3-port site RPRA (**a**) and reduced 2-port site RPRA (**b**) and for single-port site RPRA (**c**), (outliers excluded from the operation time). *RPRA* robotic posterior retroperitoneoscopic adrenalectomy

who underwent reduced 2-port RPRA revealed no difference in pain scores. Since PRA itself generally resulted in lower pain scores, reducing the number of ports would have a minimal impact on pain. Additionally, our institute routinely administers intravenous analgesics to patients in the recovery room immediately after surgery and oral analgesics regularly during hospitalization, which could create difficulty in comparing the pain scores accurately.

The operation time was the shortest in the SP group. Compared with the initial stages of the 2-port and 3-port groups, the operation time for the SP group was also significantly shorter. We attribute these shorter times to the smooth surgery proceedings with less instrument collision in the SP RPRA. Additionally, we observed no running curve in the SP group, which we attribute to the acquired laparoscopic and robotic adrenal surgery experience of the surgeons, enabling them to quickly adapt to the single-port RPRA using the SP system. Therefore, we consider that a surgeon with sufficient experience in adrenal surgery can safely and effectively perform the single-port RPRA using the SP system without encountering significant difficulties.

The present study had several limitations. It was a retrospective study with relatively few patients who underwent surgery at a single center. The surgical indications for the single-port RPRA using the SP system were also limited. Therefore, conclusions on the safety and efficacy of RPRA in patients with various indications should be drawn with caution. Further studies involving a larger patient population are required.

## Conclusion

Single-port RPA using the da Vinci SP robotic system showed the effectiveness of the surgical procedure, and outcomes were comparable to those of the conventional 3-port RPRA and reduced 2-port RPRA using the da Vinci Xi robotic system. In addition, the single-port RPRA enhanced cosmetic outcomes for patients and facilitated easier and more convenient operations for surgeons. Therefore, single-port RPRA could be a good alternative option for the treatment of adrenal tumors in selected situations.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s00464-023-10380-8.

**Author contributions** B-CK and YL: Conceptualization. B-CK, JWC, WWK, YL, T-YS, and K-WC: Data curation. YL: Investigation. B-CK, SJP, DK, JWC, WWK, YL, T-YS, and K-WC: Writing–original draft. B-CK, SJP, DK, JWC, WWK, YL, T-YS, and K-WC: Writing–review and editing.

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## Declarations

**Disclosures** Byung-Chang Kim, Douk Kwon, Shin Jeong Pak, Jae Won Cho, Won Woong Kim, Tae-Yon Sung, Ki-Wook Chung, and Yu-mi Lee have no conflicts of interest or financial ties to disclose.

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