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<td>Manuscript Title:</td>
<td>Single port partial nephrectomy: techniques and outcomes</td>
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<td>Current Management of Small Renal Masses: Is There an Optimal Choice?</td>
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Review

Single port partial nephrectomy: techniques and outcomes

Abstract

Nephron sparing surgery (NSS) is the standard treatment for cT1 renal masses, and robot-assisted partial nephrectomy (RAPN) has gained popularity due to its minimally invasive nature and potential advantages in terms of earlier discharge and lower post-operative pain. The Da Vinci SP® system offers the advantages of a smaller incision and the ability to work in smaller spaces. This narrative review aims to address the technical aspects and collect existing evidence on surgical, oncological, and functional outcomes of SP RAPN. Initial experiences with SP RAPN have demonstrated safety and feasibility, both through transperitoneal and retroperitoneal approaches. Several studies have reported similar peri- and post-operative outcomes between SP and multi-port (MP) RAPN. Overall, SP RAPN appears to be a promising technique which allows to expand the role of retroperitoneal approach. This holds the potential to expedite postoperative recovery and minimize hospital stay.

Keywords: minimally invasive surgery, renal masses, single port robot-assisted partial nephrectomy, surgical outcomes
INTRODUCTION

Nephron sparing surgery (NSS) represents the standard of treatment for cT1 renal masses. This approach has been increasingly adopted over the past years and nowadays its indication extends also to cT2 renal masses, whenever technically feasible. (1)

Robot-assisted partial nephrectomy (RAPN) is becoming de facto the new gold standard in NSS (2), as it allows lower intraoperative bleeding and faster postoperative recovery. (1)

The latest advance in the robotic urological field is represented by the Da Vinci Single Port (SP) system (Intuitive Surgical, Sunnyvale, CA). After the first description of its clinical application (3), the Da Vinci SP® system was approved by the American Food and Drug Administration (FDA) in 2014, by the Ministry of Food and Drug Safety of South Korea in 2020, and by the Japan’s Ministry of Health, Labour and Welfare In 2022. Its development has been driven by the quest to minimize skin incision and to achieve the ability to work in smaller working spaces while preserving the advantages of robotic instruments. Its safety and feasibility have now been tested in several urological procedures, and experience with this platform is growing. Greatest differences between SP and multi-port (MP) system consist in a decrease in the operative field, restrictions in the range of motion of the robotic arms, in instruments depth, and in the level of assistance from the bedside assistant(4)

Since its release, an increasing body of literature surrounding SP RAPN has been produced. SP RAPN demonstrated similar peri- and post-operative outcomes in different reports, with respect to MP RAPN, with a possible benefit in terms of opioid use. (5) Furthermore, this approach has also been tested in a retroperitoneal fashion, proving its safety and feasibility. (6)

Given the growing interest generated by this novel approach, the aim of this narrative review of the literature is to address technical aspect and to collect existing evidence about surgical, oncological, and functional outcomes.
The Da Vinci SP® surgical system

The Da Vinci SP® surgical system is composed by a single instrument arm, which encloses four instrument drives in which to insert the endoscope and three double-jointed articulating robotic instruments. Instruments enter the patient’s abdomen through a 25-mm multichannel port, that accommodates the 12 x 10 mm robotic camera, three robotic instruments with 6 mm double-jointed articulation, and a 6 mm extra laparoscopic instrument. The main difference with Da Vinci MP instruments is the additional “elbow” joint added to the robotic instruments to maintain the intracorporeal triangulation. Furthermore, the single incision approach with the single arm structure allows for a possible 360-degrees access, giving to this platform the potential to realize a one-step multiquadrant surgery.

Technical features of single port partial nephrectomy

First experience with SP RAPN was described by Kaouk et al., who investigated the safety and feasibility of the technique on three consecutive patients treated via transperitoneal approach. Authors adopted a transperitoneal approach that resembled the surgical steps performed with the MP. An operative time (OT) of 180 min, a warm ischemia time (WIT) of 25 min and estimated blood loss (EBL) of 180 mL was reported. No intraoperative complications occurred, and one patient required angioembolization due to postoperative acute bleeding. The pathology report showed negative surgical margins in all cases. Authors defined the results promising, acknowledging the presence of a learning curve and differences when compared to MP system, especially in suturing, due to the novel elbow. Since then, several studies have been added to the existing literature, either by a transperitoneal or an extraperitoneal approach. Described patient’s positioning for the transperitoneal approach include a lateral (8) or semi-lateral (9)decubitus, with the robot usually docked from the back, even though the presence of an overhead boom on which the robotic arm swivels, allows for docking from any position (Figure 1).
At our institution a transperitoneal approach is preferred for anterior and larger renal masses, in patients with no history of previous invasive abdominal surgery. A 3 cm longitudinal incision is performed on the pararectal line. After rectus fibres are spread and the posterior rectus fascia opened, the SP Access Port (Intuitive Surgical, Sunnyvale, CA) is placed into the incision, together with the single multichannel trocar (Figure 2). A short video demonstrating the placement of the SP Access Port is available as supplementary material attached to the manuscript (Supplementary material). The 12 mm AirSeal trocar can be inserted into the Access Port, or in a different site, through the same cutaneous incision but into a different opening of the rectus fascia, to guarantee adequate suction during enucleoresection. The starting configuration of the instruments is a 30° camera lens at 12 o’clock position, at 3 o’clock the monopolar curved scissors, at 6 o’clock the Cadière forceps and at 9 o’clock the fenestrated bipolar forceps. The procedure is performed as it would be done with the MP system. After adequate exposure of the kidney and opening of the Gerota’s fascia, elements of the renal pedicle are exposed. Isolation of the renal artery and vein is achieved, and adequate identification and exposure of the renal mass is obtained through defatting of the kidney. Artery clamping is achieved with the SCANLAN® Reliance Bulldog LP Clamp (Scanlan international, St Paul, MN), a bulldog clamp dedicated to SP surgery. After clamping the renal vessels, enucleoresection is carried out combining blunt and sharp dissection (Figure 3). A double layer renorraphy is performed, with a 2/0 V lock running suture for the medullary layer and a 0 Vycril interrupted suture for the cortical layer. The bulldog clamp is then removed, and the specimen bagged and extracted.

The retroperitoneal access was firstly described by Maurice et al. using the SP1098 prototype on cadaver models. Authors performed a 2.5 cm transverse skin, anterior and inferior to the tip of the 12th rib. Division of the flank musculature and subsequent exposure and incision of the thoracolumbar fascia allowed for access to the retroperitoneum.(10) Bang et al. compared the retroperitoneoscopic approach to the transperitoneal approach, reporting comparable outcomes. No significant difference in terms of OT and console time was observed between the two approaches. In
the two groups WIT, EBL and length of hospital stay (LoS) were similar, as were post-operative functional outcomes (serum creatinine and eGFR). (11)

A simplified approach for retroperitoneal SP RAPN has been described by Pellegrino et al. in a recent case-series. The supine anterior retroperitoneal access (SARA) approach aimed at providing a safer, more effective, and consistent method to retroperitoneal surgery. The retroperitoneum is accessed through a 3 cm incision at approximately the McBurney point, 3 cm medial and 3 cm caudal to the anterior superior iliac spine. No dilating balloon is needed since a careful finger dissection is sufficient to move the parietal peritoneum away from the incision site. The retroperitoneal adipose tissue is dissected in the direction of the posterior region of the retroperitoneal cavity, until exposure of quadratus lumborum muscle laterally and iliopsoas muscle medially. At this point ureter is identified and followed to the renal pelvis and renal hilum. The rest of the surgical procedure replicates RAPN standard steps. Analysis of post-operative outcome showed a mean WIT of 25 ± 7 min and a mean OT of 109 ± 18 min, with a mean tumor size of 37 ± 12.5 mm. No patients required intraoperative or postoperative blood transfusion and the same-day discharge rate was 84%. (12) The first three cases with the SARA approach were performed at our institution, with promising results. No intra-operative and post-operative complications were observed, and all the patients were discharged on post-operative day one, supporting the feasibility and safety of this technique.
Figure 1. Docking of Da Vinci SP® surgical system

Figure 2. The SP access port with the multichannel port and robotic instruments.
Figure 3. Intraoperative view during single port robot-assisted partial nephrectomy.

Surgical, functional, and oncological outcomes

The most consistent evidence on SP RAPN regards young patients with low complexity (R.E.N.A.L. score ≤6) (13) small renal masses, defined as renal lesion ≤4 cm. Shukla et al. reported results of 12 patients with a mean age of 57.8 years (SD ±11) and a mean tumor size of 3.1 cm (SD ±2.2), 83% of which with a R.E.N.A.L. score ≤6. A mean OT for SP RAPN of 171.6 min (SD ±40.5) was reported, with a mean EBL of 68.3 mL (SD 74.6) and a WIT <25 min. There were no intra-operative conversions or early postoperative complications, with a median LoS of 1.2 days (range 1–3 days) and no readmission within the 90 days post-operative period. No significant changes between pre-operative and postoperative haematocrit (41.9, ±SD 4.3 to 39.2, ±SD 3.4, p =0.1) or eGFR (57.8, ±SD 4.9 to 58.6, SD ±3.2, p =0.1) was registered. Most common histology was clear cell renal cell carcinoma (ccRCC) and only one patient had a positive surgical margin (PSM). (14)
Another retrospective analysis of 30 patients undergoing SP RAPN either by transperitoneal or retroperitoneal approach led to similar results. In this case series patients were younger (mean age 50.1 ± 11.9 years) and small low complexity tumours were treated (dimension: 2.1 ± 0.9 cm; R.E.N.A.L. score 4.27 ± 0.4). Similar outcomes were achieved in this population (mean OT: 108 ± 43.1 min; mean WIT 11.5 ± 7.3 min; mean EBL 136.3 ± 134.4 min). Only one patient suffered from early post-operative complication (triglycerides in the drainage tube), treated conservatively, and no post-operative bleeding events were reported. A LoS of 4.1 ± 1.0 days was reported, but it is important to consider the influence on time to discharge of health policies within the Korean health system when comparing these results to patients in the United States. No significant difference was observed when comparing transperitoneal to retroperitoneal approach. For what concerns post-operative outcomes, no PSM on final pathology report and no significant decrease in post-operative renal function was observed, regardless of the surgical technique.(11)

Francavilla et al. analysed 14 consecutive patients undergoing SP transperitoneal RAPN in a retrospective manner. Median age was 54.5 years (IQR 48.0-71.0), and all the renal masses were ≤4 cm, with a median R.E.N.A.L. score of 6 points (IQR, 5.3-7). In this cohort median OT was 202 min (IQR, 162-231), WIT 18 min (IQR, 15-24) and EBL 50 mL (IQR, 43-225). One intraoperative (Mild liver capsule injury) and two postoperative (retroperitoneal hematomas treated with selective embolization, Clavien IIIa) complications were observed. Nevertheless, median LoS was 1 (IQR, 1-2) and median pain score at discharge was 0 (0-4). From an oncological perspective, PSM was reported in one patient (7%) but no sign of recurrence was encountered after 5 months follow-up.(8) Baseline characteristics and peri-operative outcomes of each study are summarised in Table 1.

Table 1. Pre-operative, intra-operative and post-operative features of SP RAPN

<table>
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<tr>
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<th>Approach</th>
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<td>2018</td>
<td>3</td>
<td>Transperitoneal</td>
<td>na</td>
<td>OT: 180 min</td>
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<td>Study</td>
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**Abbreviations:** EBL (estimated blood loss); LoS (length of stay); OT (operative time); PSM (positive surgical margin); WIT (warm ischemia time)

**Differences between single port and multi-port RAPN**

The widespread use of the MP robotic platform imposes a comparison, in terms of surgical features and peri-operative outcomes, between this and the more innovative SP system for what concerns NSS. A prospective multicentre cohort study was conducted on the Single Port Advanced Research Consortium (SPARC) database to assess and compare outcomes of SP and MP RAPN. A total of 1726 patients undergoing RAPN at 9 institutions in the United States, between 2015 and 2021, were included. After propensity score matching, the two subgroups were similar in terms of age (58 ±12 years vs 59 ±12 years; p=0.6), mean tumor size (2.94 ±1.34 cm vs 2.96 ±1.61 cm; p=0.9) and median R.E.N.A.L score (6 [IQR: 5-8] vs 6 [IQR: 5-8]; p=0.8). SP surgery had longer mean ischemia time (18.29 ±10.4 min vs 13.79 ±6.29 min; p<0.01), but no difference in EBL (89.38 ±111.19 mL vs 112.46 ±157.29 mL; p = 0.1), and OT (137.0 ±59.5 min vs 142.3 ±60.6 min; p = 0.4). With regards to post-operative surgical outcomes, LoS (1.19 ±1.9 days vs 1.33 ±1.0 days; p=0.4) and rate of complications of any grade (8.2% vs 6.1%; p = 0.2) were similar between SP and MP RAPN. No significant difference was observed also in terms of oncological outcomes, since PSM rate (6.1% vs 4.7; p=0.2) was comparable in the two groups. Authors stratified the entire cohort by tumor
complexity, reporting a longer WIT in the low (16.31–11.08 min vs 11.61–5.23 min; p=0.002) and intermediate complexity groups (19.12–9.18 min vs 15.32–6.26 min; p=0.019) for SP approach. On the contrary OT for high complexity SP RAPN was shorter (108.27–39.09 vs 167.71–55.5 min) than MP RAPN. Other perioperative outcomes were comparable between the two approaches, despite the tumour complexity.(15)

A systematic review and meta-analysis by Li et al. assessed the available comparative studies between SP RAPN and MP RAPN. The two groups were homogeneous, since no significant difference was observed in terms of baseline characteristics (age, p = 0.71; tumor diameter, p = 0.34; RENAL score, p = 0.29). No significant difference in terms of OT (p=0.19) was observed when comparing SP RAPN to MP RAPN. WIT was significantly longer for SP RAPN than for MP RAPN (weight mean difference [WMD] 3.46 min, 95% CI 1.03, 5.90; p<0.01). On the other hand, EBL was lower in SP RAPN group (WMD – 27.16 ml, 95% CI – 56.90, 2.58; p=0.07), without reaching statistical significance. An overall complication rate <10% was reported, with no statistical difference in terms of overall complication (SP RAPN 7.3% vs MP RAPN 8.7%, p=0.9) intraoperative complications (SP RAPN 0% vs MP RAPN 2%, p = 0.60) and major complications (SP RAPN 3.4% vs MP RAPN 3.7%, p = 0.84). The two approaches appeared comparable also in terms of oncological outcomes since no difference in PSM rate was registered (p=0.9).(16)

Discussion

The introduction of the Da Vinci SP® platform represents the latest innovation in the field of minimally invasive urological surgery, aiming to provide patients with surgical procedures that offer non-inferior outcomes with respect to traditional surgery, along with advantages in terms of invasiveness, LoS, and postoperative pain. We critically reviewed and summarized the available evidence on SP RAPN, comparing them to traditional MP RAPN. Although many of the included studies are based on preliminary experiences with limited sample sizes, our study reveals several noteworthy findings.
The surgical quality of a RAPN has been defined by the so called “Trifecta” outcomes, which has been defined in several ways but it is in general the concomitant occurrence of short WIT, negative surgical margins, and no perioperative complications.(17) According to these outcomes, our results highlight how SP RAPN represents a safe and feasible option for NSS.

There is no consensus regarding the optimal cut-off for WIT. While some authors suggest that a maximum time of 25-30 minutes is safe to prevent ischemic damage (18), other studies dispute these findings and report that longer ischemia time does not impact post-operative renal function.(19) A WIT of less than 25 minutes was consistently observed across different studies, thereby demonstrating the effectiveness of SP RAPN in controlling the renal hilum. Another crucial factor in preserving post-operative renal function is EBL. An EBL exceeding 100 mL was significantly associated with a higher risk of post-operative chronic kidney disease in patients undergoing NSS.(20) Encouraging results regarding this aspect emerge from our findings, since most of the studies reported an EBL <100 mL. However, it is important to acknowledge that most of these observations were based on a cohort of patients who underwent surgery for smaller and less complex renal masses.

Convincing evidence arises from the comparison between SP and MP surgery. Although SP surgery had a longer WIT, there were no significant differences in EBL, OT, LoS, or complication rates. Oncological outcomes, as indicated by the rate of PSM, were also comparable between the two groups. These direct comparisons suggest that SP RAPN is a valid alternative to MP RAPN for NSS.

Great differences between SP and MP systems exist, therefore imposing a learning curve, even for experienced robotic surgeons. Even though not specifically evaluated for RAPN, a considerable learning curve has been suggested for robot-assisted radical prostatectomy, attributed to variances in the articulation of instruments, their rigidity, and the level of bedside assistance in the SP approach(21). The optimal distance between the target and the robotic cannula to ensure a proper articulation of the instruments is 5-10 cm.(22) Therefore, robotic cannula and instruments, as well as any accessory trocar, are placed above the skin, according to the floating docking technique. This
allows for intracorporeal maximum triangulation. Furthermore, the endoscope needs more frequent adjustment with respect to MP system, given the smaller operating field with this approach. This was compensated by the addition of two set of articulations on the camera, to ensure wider movements: “camera adjust”, a fixed articulation, that allows arms adjustment while the endoscope is still, and “camera control” which make the camera move independently from the other instruments. A third method, called the “Cobra method”, is a configuration that enables the camera to extend outward and move sideways in relation to the working instruments. If these extra tools are not enough, the entire arm attached to the trocar can be repositioned with the relocation feature. An additional foot clutch was included to enable for this novel set of movements of the camera and the instruments.

Overall, early outcomes of SP RAPN are promising. The SP system offers potential advantages such as reduced postoperative pain, earlier hospital discharge, and improved cosmetic results. While further studies are necessary to validate these findings and assess long-term outcomes, the growing body of evidence supports the feasibility, reproducibility, and safety of SP surgery for PN.

CONCLUSION

SP RAPN is rapidly emerging as a novel and promising approach for the treatment of small renal masses. Initial comparative studies suggest that SP RAPN can offer similar peri- and postoperative outcomes compared to MP RAPN, with potential benefits such as lower opioid use and improved cosmetic results. One of the main features of this novel technology is that allows to expand the role of retroperitoneal kidney surgery. This can translate into faster postoperative recovery which could ultimately lead to the implementation of outpatient surgery. To date, SP RAPN has been used mostly for low to intermediate complexity tumors, but maturing experience will allow to extend indications to more complex ones. Further research is warranted to corroborate early promising studies and to better define the role of SP RAPN.
Availability of Data and Materials
Not applicable.

Financial Support and Sponsorship
None.

Conflicts of Interest
All authors declared that there are no conflicts of interest.

Ethical Approval and Consent to Participate
Not applicable.

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<td>Transperitoneal</td>
<td>Mean Age: 57.8 yrs Mean tumor size: 3.1 cm RENAL score: ≤6 (83%)</td>
<td>Mean OT: 171.6 min WIT: &lt;25 min Mean EBL: 68.3 mL</td>
<td>Complication rate: 0% Mean LoS: 1.2 days PSM: 1%</td>
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<td>Bang et al.</td>
<td>2023</td>
<td>30</td>
<td>Transperitoneal and retroperitoneal</td>
<td>Mean Age: 50.1 yrs Mean Tumor size: 2.1 cm Mean RENAL score: 4.27</td>
<td>Mean OT: 108 min Mean WIT: 11.5 min Mean EBL: 136.3 mL</td>
<td>Complication rate: 3% Mean LoS: 4.13 days PSM: 0%</td>
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<td>Francavilla et al.</td>
<td>2022</td>
<td>14</td>
<td>Transperitoneal</td>
<td>Median Age: 54.5 yrs Median Tumor size: 2.6 cm Median RENAL score: 6</td>
<td>Median OT: 202 min Median WIT: 18 min Median EBL: 50 mL</td>
<td>Complication rate: 14% Mean LoS: 1 days PSM: 7%</td>
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<td>Pellegrino et al.</td>
<td>2023</td>
<td>12</td>
<td>Retroperitoneal</td>
<td>Mean Age: 57 yrs Mean Tumor size: 3.7 Median RENAL score: 5</td>
<td>Mean OT: 109 min Mean WIT: 25 Mean EBL: 120 mL</td>
<td>Complication rate: 8% PSM: 8% Same-day discharge: 83%</td>
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**Abbreviations:** EBL (estimated blood loss); LoS (length of stay); OT (operative time); PSM (positive surgical margin); WIT (warm ischemia time)