

Review

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Single port partial nephrectomy: techniques and outcomes

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How to cite this article: Ditunno F, Franco A, Manfredi C, De Nunzio C, De Sio M, Antonelli A, Autorino R. Single port partial nephrectomy: techniques and outcomes. *Mini-invasive Surg* 2023;7:36. <https://dx.doi.org/10.20517/2574-1225.2023.62>

Received: 7 Jun 2023 **First Decision:** 16 Oct 2023 **Revised:** 17 Oct 2023 **Accepted:** 6 Nov 2023 **Published:** 13 Nov 2023

Academic Editor: Chi-Fai Ng **Copy Editor:** Pei-Yun Wang **Production Editor:** Pei-Yun Wang

Abstract

Nephron-sparing surgery 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 Single Port® (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 RAPN. Overall, SP RAPN appears to be a promising technique that expands the role of retroperitoneal approaches. This holds the potential to expedite post-operative recovery and minimize hospital stays.

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



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INTRODUCTION

Nephron-sparing surgery (NSS) represents the standard of treatment for cT1 renal masses. This approach has seen increasing adoption over the past years, and today, its indications have also extended to include cT2 renal masses when 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 post-operative recovery compared to open and laparoscopic partial nephrectomy^[1].

The latest advance in the robotic urological field is represented by the Da Vinci Single Port® (SP) system (Intuitive Surgical, Sunnyvale, CA). Following its initial clinical description^[3], the Da Vinci SP® system was approved by the American Food and Drug Administration (FDA) in 2014, the Ministry of Food and Drug Safety of South Korea in 2020, and Japan's Ministry of Health, Labour and Welfare in 2022. Its development aims at minimizing skin incisions and facilitating 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^[4]. The greatest differences between SP and multi-port (MP) systems consist of a reduced operative field, restrictions in the range of motion of the robotic arms, shallower instrument depth, and a decreased level of assistance from the bedside assistant^[5].

Since its approval, an increasing body of literature has emerged on SP RAPN^[6,7]. 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^[8]. Furthermore, this approach has also been tested in a retroperitoneal fashion, proving its safety and feasibility^[9].

Given the growing interest in this novel approach, this narrative review of the literature aims to address technical aspects and collect existing evidence about surgical, oncological, and functional outcomes of SP RAPN.

THE DA VINCI SP® SURGICAL SYSTEM

The Da Vinci SP® surgical system is composed of 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 mm × 10 mm robotic camera, three robotic instruments with 6 mm double-jointed articulation, and a 6 mm extra laparoscopic instrument [Figure 1]. 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 possible 360-degree access, giving this platform the potential to realize one-step multiquadrant surgery.

Technical features of single port partial nephrectomy

The initial 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 a transperitoneal approach. The authors adopted a transperitoneal approach that resembled the surgical steps performed with the MP approach. An operative time (OT) of 180 min, a warm ischemia time (WIT) of 25 min, and an estimated blood loss (EBL) of 180 mL was reported. No intraoperative complications occurred, and one patient required angioembolization due to post-operative acute bleeding. The pathology report showed negative surgical margins in all cases. The authors defined the results as promising, acknowledging the presence of a learning curve and differences when compared to the MP system, especially in suturing, due to the novel elbow^[6].



Figure 1. An overview of the Da Vinci SP® surgical system: a single instrument arm, including four instrument drives in which to insert the endoscope and three double-jointed articulating robotic instruments. SP: Single port.

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 can include a lateral^[10] or semi-lateral^[11] 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 2].

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 fibers are spread and the posterior rectus fascia is opened, the SP Access Port (Intuitive Surgical, Sunnyvale, CA) is placed into the incision, together with the single multichannel trocar [Figure 3]. A short video demonstrating the placement of the SP Access Port is available as [Supplementary Material](#) attached to the manuscript. 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 the 12 o'clock position, the monopolar curved scissors at 3 o'clock, the Cadière forceps at 6 o'clock, and the fenestrated bipolar forceps at 9 o'clock. 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 4]. Double-layer renorrhaphy is performed, with a 2/0 V lock running suture for



Figure 2. Docking of the Da Vinci SP® surgical system. SP: Single port.

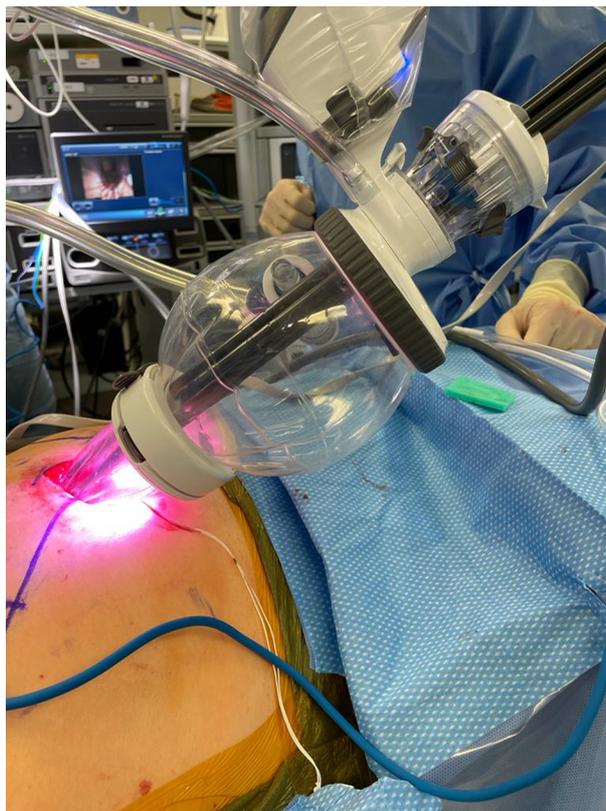


Figure 3. The SP access port with the multichannel port and robotic instruments. SP: Single port.

the medullary layer and a 0 Vycril interrupted suture for the cortical layer. The bulldog clamp is then removed, and the specimen bagged (Endo Catch™, Medtronic, Dublin, Ireland) and extracted.

The retroperitoneal access was first described by Maurice *et al.* using the SP1098 prototype on cadaver models. The 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^[12]. Bang *et al.* compared the retroperitoneoscopic approach to the transperitoneal approach, reporting comparable outcomes. No significant difference in terms of OT and

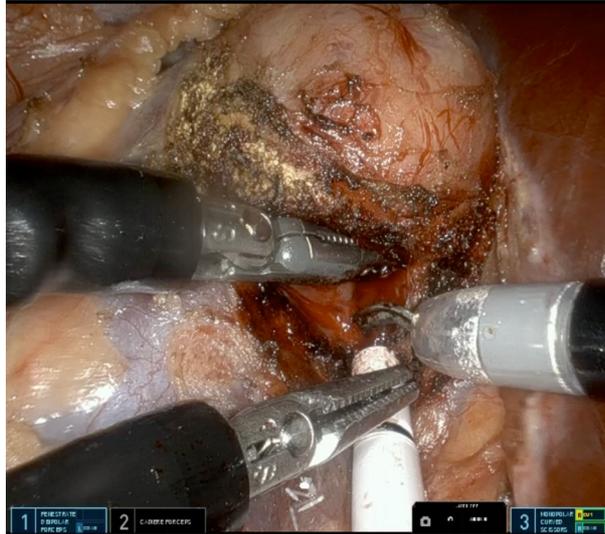


Figure 4. Intraoperative view during single port robot-assisted partial nephrectomy.

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 estimated glomerular filtration rate (eGFR)]^[13].

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 was aimed at providing a safer, more effective, and consistent method for 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 (SD) WIT of 25 ± 7 min and a mean (SD) OT of 109 ± 18 min, with a mean (SD) tumor size of 37 ± 12.5 mm. No patients required intraoperative or post-operative blood transfusion, and the same-day discharge rate was 84%^[14]. 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.

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)^[15] small renal masses, defined as renal lesions ≤ 4 cm. Shukla *et al.* reported results of 12 patients with a mean (SD) age of 57.8 years (± 11) and a mean (SD) tumor size of 3.1 cm (± 2.2), 83% of which with a R.E.N.A.L. score ≤ 6 . A mean (SD) OT for SP RAPN of 171.6 min (± 40.5) was reported, with a mean (SD) EBL of 68.3 mL (± 74.6) and a WIT < 25 min. There were no intra-operative conversions or early post-operative complications, with a median LoS of 1.2 days (range 1-3 days) and no readmission within the 90-day post-operative period. No significant changes between mean (SD) pre-operative and post-operative hematocrit (41.9 ± 4.3 to 39.2 ± 3.4 , $P = 0.1$) or mean (SD) eGFR (57.8 ± 54.9 to 58.6 ± 3.2 , $P = 0.1$) was registered. The most common histology was clear cell renal cell carcinoma (ccRCC), and only one patient

had a positive surgical margin (PSM)^[16].

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 (SD) age 50.1 ± 11.9 years], and small low complexity tumors were treated [mean (SD) dimension: 2.1 ± 0.9 cm; R.E.N.A.L. score 4.27 ± 0.4]. Similar outcomes were achieved in this population [mean (SD) OT: 108 ± 43.1 min; mean (SD) WIT 11.5 ± 7.3 min; mean (SD) EBL 136.3 ± 134.4 min]. Only one patient suffered from an early post-operative complication (triglycerides in the drainage tube), treated conservatively, and no post-operative bleeding events were reported. A mean (SD) 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 approaches. As for post-operative outcomes, no PSM on the final pathology report and no significant decrease in post-operative renal function were observed, regardless of the surgical technique^[13].

Francavilla *et al.* analyzed 14 consecutive patients undergoing SP transperitoneal RAPN in a retrospective manner. The 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 six 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 post-operative (retroperitoneal hematomas treated with selective embolization, Clavien IIIa) complications were observed. Nevertheless, the median LoS was 1 (IQR, 1-2), and the 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 five months of follow-up^[10]. Data from available literature are summarized in [Table 1](#).

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 1,726 patients undergoing RAPN at nine institutions in the United States between 2015 and 2021 were included. After propensity score matching, the two subgroups were similar in terms of mean (SD) age (58 ± 12 years *vs.* 59 ± 12 years; *P* = 0.6), mean (SD) 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 (SD) ischemia time (18.29 ± 10.4 min *vs.* 13.79 ± 6.29 min; *P* < 0.01) but no difference in mean (SD) EBL (89.38 ± 111.19 mL *vs.* 112.46 ± 157.29 mL; *P* = 0.1) and mean (SD) OT (137.0 ± 59.5 min *vs.* 142.3 ± 60.6 min; *P* = 0.4). With regards to post-operative surgical outcomes, mean (SD) 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 in terms of oncological outcomes since the PSM rate (6.1% *vs.* 4.7%; *P* = 0.2) was comparable in the two groups. The 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 the 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 tumor complexity^[17].

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

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

Author	Year	N of patients	Approach	Pre-operative features	Intra-operative outcomes	Post-operative outcomes
Kaouk et al. ^[6]	2018	3	Transperitoneal	Na	OT: 180 min WIT: 25 min EBL: 180 mL	Complication rate: 33.3% PSM: 0%
Shukla et al. ^[16]	2020	12	Transperitoneal	Mean age: 57.8 years Mean tumor size: 3.1 cm RENAL score: ≤ 6 (83%)	Mean OT: 171.6 min WIT: <25 min Mean EBL: 68.3 mL	Complication rate: 0% Mean LoS: 1.2 days PSM: 1%
Bang et al. ^[13]	2023	30	Transperitoneal and retroperitoneal	Mean age: 50.1 years Mean tumor size: 2.1 cm Mean RENAL score: 4.27	Mean OT: 108 min Mean WIT: 11.5 min EBL: 136.3 mL	Complication rate: 3% Mean LoS: 4.13 days PSM: 0%
FrancaVilla et al. ^[10]	2022	14	Transperitoneal	Median age: 54.5 years Median tumor size: 2.6 cm Median RENAL score: 6	Median OT: 202 min Median WIT: 18 min Median EBL: 50 mL	Complication rate: 14% Median LoS: 1 day PSM: 7%
Pellegrino et al. ^[14]	2023	12	Retroperitoneal	Mean age: 57 years Mean tumor size: 3.7 Median RENAL score: 5	Mean OT: 109 min Mean WIT: 25 Mean EBL: 120 mL	Complication rate: 8% PSM: 8% Same-day discharge: 83%

EBL: Estimated blood loss; LoS: length of stay; OT: operative time; PSM: positive surgical margin; RAPN: robot-assisted partial nephrectomy; SP: single port; WIT: warm ischemia time.

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 the 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 also appeared comparable in terms of oncological outcomes since no difference in the PSM rate was registered ($P = 0.9$)^[18].

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 post-operative pain. However, this platform still represents a work in progress, with the aim of overcoming existing limitations. Some of these limitations have already been addressed, such as instrument strength and camera movements. However, others, such as the limited availability of dedicated tools, remain unsolved. 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^[19]. 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 min is safe to prevent ischemic damage^[20], other studies dispute these findings and report that longer ischemia time does not influence post-operative renal function^[21]. A WIT of less than 25 min 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^[22]. 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^[23]. The optimal distance between the target and the robotic cannula to ensure proper articulation of the instruments is 5-10 cm^[24]. 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^[24]. Furthermore, the endoscope needs more frequent adjustments with respect to MP systems, given the smaller operating field with this approach^[5]. This challenge was compensated by the addition of two sets of articulations on the camera to ensure wider movements. These articulations include “camera adjust”, a fixed articulation that allows arm adjustments while the endoscope remains still, and “camera control”, which makes 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 this novel set of movements of the camera and the instruments.

The unique features of the SP system, such as camera flexibility and greater instrument maneuverability, make it well-suited for operating within a confined surgical field. This technical advantage can be optimally harnessed in the retroperitoneal space. Hence, an extraperitoneal approach, particularly suitable for the SP system^[25], has the potential to enhance the benefits typically associated with retroperitoneal surgery. The integration of these advantages, such as improved control over hilar structures, reduced OT, shorter LoS, and decreased post-operative discomfort and pain, with the SP system has the potential to further improve surgical outcomes.

Overall, early outcomes of SP RAPN are promising. The SP system offers potential advantages, such as reduced post-operative pain, earlier hospital discharge, and improved cosmetic results. Nevertheless, it must be considered that existing evidence primarily originates from retrospective studies with limited sample sizes conducted at high-volume centers by experienced surgeons, which hamper their generalizability. Hence, while the growing body of evidence supports the feasibility, reproducibility, and safety of SP surgery for PN, further studies are necessary to validate these findings and assess long-term outcomes.

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 post-operative 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 it allows the expansion of the role of retroperitoneal kidney surgery. This can translate into faster post-operative 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 extend its indications to more complex cases. Further research is warranted to corroborate early promising studies and better define the role of SP RAPN.

DECLARATIONS

Authors' contributions

Made substantial contributions to the conception and design of the work: Ditunno F, Franco A, Autorino R

Drafted the manuscript: Ditunno F

Performed data analysis and interpretation: Autorino R, Ditunno F, Manfredi C

Critically revised the work: Autorino R, Antonelli A, De Nunzio C, De Sio M

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.

Consent for publication

Not applicable.

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