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Current status of robot-assisted partial nephrectomy

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Partial nephrectomy has shown both improved overall patient survival and more effective preservation of renal function, when compared with radical nephrectomy. Robot-assisted partial nephrectomy has several potential advantages over the laparoscopic approach. Robotic assistance allows urologists to perform this complex reconstructive procedure more quickly, with improved precision and dexterity, tremor elimination and improved visualization. The present article aims to delineate the dynamics of patient preparation and surgical team, surgical technique and postoperative care. The oncological outcomes and disease-free survival of partial nephrectomy have been found to be equivalent to open partial nephrectomy [1–4].

What's known on the subject? and What does the study add?
The use of robotic assistance for the partial nephrectomy procedure has emerged as an alternative that may help some of the technical challenges of laparoscopic partial nephrectomy. The main concerns in laparoscopic partial nephrectomy relates to a steeper 'learning curve', prolonged warm ischaemia times and the potential for postoperative haemorrhage.

The article delineates the dynamics of patient preparation, the surgical team, surgical technique & post-operative care to conclude that robotic-assisted partial nephrectomy is a viable alternative to both open and laparoscopic techniques.

KEYWORDS

robotic surgery, urology, nephrectomy

INTRODUCTION

With increasing access to abdominal imaging for a wide range of indications, the incidental finding of a small renal mass is becoming more common and, therefore, the demand for minimally invasive partial nephrectomy as a definitive treatment is also increasing. Partial nephrectomy has shown improved overall patient survival, as well as more effective preservation of renal function, compared with radical nephrectomy [1,5,6]. It is an established treatment for renal masses <4 cm in size [7]. The use of robotic assistance for this procedure has emerged as an alternative that may help some of the technical challenges of laparoscopic partial nephrectomy (LPN) [8–10]. The main concerns regarding LPN relate to a steeper 'learning curve', prolonged warm ischaemia times (WITs) and the potential for postoperative haemorrhage [11].. An evaluation of the learning curve of LPN has shown that mastery of the technique performed under warm ischaemia could not be attained until 565 procedures had been completed [12], compared with much smaller numbers in robot-assisted partial nephrectomy (RAPN) of about 30 cases or fewer [9,13,14]. RAPN has enabled less experienced surgeons to perform the same procedure efficiently, safely and with improved control.

Robot-assisted partial nephrectomy currently uses the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) [12,18]. Increased degrees of freedom are provided by the Endowrist instruments (Intuitive Surgical) compared with standard laparoscopy [15]. Aspects of RAPN, such as tumour excision and renorrhaphy, have become more straightforward and accessible to a wider range of surgeons through the use of robotics. Since its introduction by Gettman *et al.* in 2004 [15], there has been a steady increase in RAPN, with >300 cases reported between 2009 and 2010 [16–19]. It is becoming the technique of choice for most stage T1a tumours, where the technology and expertise is available. Its feasibility has been demonstrated for moderately or even highly complex renal masses [20,21].

PATIENT-SPECIFIC PREPARATION

Patients with functionally or anatomically solitary kidneys or those with evidence of tumour in the contralateral kidney are absolute/imperative indications for partial nephrectomy [22]. Partial nephrectomy has increasingly become a routine surgical procedure in most patients with tumours <4 cm in size, since its oncological safety has been proven in many large series. It can also be carried out in selected patients with tumours >4 cm in size and those with complex and endophytic tumours where preservation of renal function is highly desirable. Such cases are being successfully managed in high volume centres [23]. A radical nephrectomy (usually laparoscopic) is recommended if the patient does not meet any of the above criteria.

TABLE 1 Instruments used during RAPN procedures

Techique	Instrument
Dissection	Hot shears monopolar curved scissors or monopolar hook (right hand). Fenestrated bipolar forceps, Maryland forceps (Mediflex, Islandia, NY, USA) or Prograsp forceps (Intuitive Surgical).
Excision	Hot shears monopolar curved scissors or monopolar hook (right hand). Fenestrated bipolar forceps, Maryland forceps or Prograsp forceps.
Renal reconstruction	Two large needle drivers OR one needle driver (right hand) and forceps (left hand)
To assist the console surgeon	5-mm laparoscopic grasper, scissors and needle driver; laparoscopic bulldog clamp applier; 5 mm and 10-mm Hem-o-lock clip applier (Teleflex); long suction tip and irrigator; 10-mm specimen extraction bag; Jackson-Pratt drain with suction bulb.

All patients being considered for RAPN undergo a metastatic evaluation. This includes contrast-enhanced abdominal CT or MRI, chest X-ray and a full blood evaluation (complete blood count, electrolytes, creatinine, coagulation studies and liver function tests) [24]. The number of renal arteries, veins and any aberrant renal vasculature is noted from the contrast-enhanced CT scan, which usually accurately illustrates the renal blood supply [10]. Patients with clinical signs and symptoms of potential metastases have additional imaging. The preoperative aspects and dimensions used for an anatomical (PADUA) classification are used as a means to select suitable patients, particularly early in the series [25].

SURGICAL TEAM AND INSTRUMENTS USED

The surgical team consists of at least one operating console surgeon, one bedside surgical assistant and one scrub nurse. Normally the operating surgeon scrubs initially to assist in robotic port placement and patient preparation before sitting at the robotic console, whereas the bedside members of the surgical team remain scrubbed throughout the procedure [24]. The instruments used by both the console surgeon and the bedside assistant are listed in Table 1. In addition to this, optional fourth robotic arm instruments can be used, such as a dual blade retractor, double fenestrated retractor or the robotic Prograsp (Intuitive Surgical) instrument. The robotically applied bulldog clamps and drop-in robotic manipulated ultrasound probes are controlled by the console surgeon and add to the safety and independence of the primary surgeon. Four to six ports are placed, depending on whether a fourth arm is used and whether a liver retractor is required for right-sided cases.

SURGICAL TECHNIQUE

The same general principles as used in open partial nephrectomy guide all RAPN procedures, with slight variations in surgical technique owing to the minimally invasive approach [26]. This variation largely reflects surgeon-specific preferences. The patient is most commonly placed in flank position with a lateral tilt of 45° [10]. In the majority of cases the camera and trocar configuration is such that the camera is placed laterally (at the lateral border of rectus abdominis, about 2 cm cranial to the umbilicus), with the working ports triangulated 8–10 cm away in a perpendicular line to the line drawn from the camera port to the hilum [27]. Many centres are now offering a retroperitoneal approach to RAPN, which is indicated in posterior tumours or those patients with previous major abdominal surgery.

During RAPN, after the robotic port placement, the bowel is reflected. The renal vessels are identified and isolated, often with slings. The kidney is fully mobilized and renal fat excised other than over the tumour. This is similar to the open approach [11]. The hilar vessels are then clamped with laparoscopic bulldog clamps (e.g. MicroFrance, Surgical Instrument Group Holdings Ltd, Surrey, UK or Aesculap, Center Valley, PA, USA), robotic bulldog clamps (Scanlan, St. Paul, MN, USA) or laparoscopic Satinsky clamps (Bolton Surgical Ltd., Sheffield, UK) and the WIT recording begins. The tumour is excised with cold scissors or using diathermy energy and a deep margin biopsy may be taken. Dissolvable sutures are placed to over-sew major vessels and the collecting system if required often by use of a suture anchored by a Weck Hem-o-Lock clip (Teleflex, Research Triangle Park, NC, USA) and secured with another clip at completion. Renorrhaphy and closure of the renal defect is increasingly being performed using the sliding clip technique via Hem-o-Lock clips which has the advantages of being quick, simple and requiring no knots to be tied, and the tension can be sequentially increased if required [9]. WIT should be <30 min with some experts managing to complete the procedure in <20 min [26]. Non-clamping techniques or selective arterial occlusion can be used in smaller exophytic lesions, although blood loss may be increased.

In a recent large study of 183 patients who underwent RAPN the technique was reviewed [26]. Patient positioning was identical in all procedures, with the patient being placed in a flank position. To gain access, the medial trocar configuration was frequently used, in which the camera is located medially close to the umbilicus. Two camera ports were introduced along the mid-axillary line, with one a few cm below the costal margin and the other a few cm above the anterior superior iliac spine. The assistant port was placed medially and just caudally to the camera ports. Tumours were excised using cold robotic scissors and, once complete, the cortex of the resection bed was often cauterized for haemostasis [26].

Haemostatic agents can be used such as Evicel (Johnson & Johnson, New Brunswick, NJ, USA) or Floseal (Baxter, Deerfield, IL, USA) as an adjunct to the renorrhaphy closure. A non-suction drain is placed near the kidney.

Table 2 RAPN studies

Reference	No. of patients	Mean tumour size, cm	Mean operative time, min	Mean WIT, min	Mean EBL, mL	Length of stay, days	Complications *n* (%)	
							RAPN	LPN
Kaul *et al.* [10]	10	2	155	21	92	1.5	2 (20)	NR
Rogers *et al.* [28]	11	3.8	202	28.9	220	2.6	NR	NR
Benway *et al.* [9]	129	2.8	189	19.7	155	2.4	12 (10.2)	11 (8.5)
Michli *et al.* [18]	20	2.7	142	28	263	2.8	3 (15)	NR
Benway *et al.* [16]	50	2.5	145.3	17.8	140.3	2.5	5 (10)	NR
Wang *et al.* [19]	40	2.5	140	19	136	2.5	8 (20)	9 (15)
Benway *et al.* [26]	183	2.9	210	23.9	131.5	3.2	13 (13)	7 (3.8)
Patel *et al.* [17]	71	5.0	238–275.5	20–25	100	2.0	19 (27)	NR
White *et al.* [29]	67	3.7	180	19.0	200	3.0	15 (22)	NR
Williams *et al.* [30]	27	2.5	233	18.5	179.6	2.51	5 (18.5)	1 (4)

EBL, estimated blood loss; NR, not reported.

POSTOPERATIVE CARE

After RAPN, patients are given i.v. fluids, prophylaxis for deep vein thrombosis, antibiotics and analgesics as necessary. The mean stay in hospital for patients undergoing RAPN is 2–3 days [24].

COMPLICATIONS OF RAPN

As seen in Table 2 [9,10,16–19,26,28–30], the complication rates of RAPN are similar to those of LPN. Significant intra- or postoperative haemorrhage occurs in 2–4.9% of all partial nephrectomy cases [3,31,32]. Depending on the source of the bleeding, there are several techniques used to control it. Haemorrhage during dissection of the hilum can usually be controlled using a lap pad or swab to tamponade the bleeding, allowing the surgeon to work on a different area for a few minutes [24]. A grasper can be used to occlude any identified bleeding vessel until cautery or clips control the bleeding. Haemorrhage after vascular clamping can also occur; and potential reasons for this include:

- a branch of the renal artery was missed during clamping;
- the kidney is still being partially perfused by an accessory artery, often from the adrenal gland;
- the clamps are not effectively occluding the vessels.

Haemorrhage after clamping could be avoided with the use of two additional bulldog clamps, one placed across the renal hilum and the other placed in the fat between the adrenal gland and the kidney. The bulldog clamp across the renal hilum encompasses all the branches of the renal artery. The second bulldog clamp placed in the fat could occlude any accessory branches. Haemorrhage can also be prevented, particularly in cases with complex renal vessels, with the use of a robotic Doppler probe, which helps identify accessory vessels [33].

Major complications (Clavien grade 3–4) include postoperative haemorrhage requiring open exploration, pseudo-aneurysms requiring embolization, urine leaks requiring retrograde ureteric stenting, hepatic or splenic laceration and subcapsular renal haematoma development. Minor complications (Clavien grade 1–2) include cellulitis surrounding the incision, urinary infection, macroscopic haematuria and wound problems [26].

Patients with previous abdominal surgery and a subsequent increased risk of intra-abdominal adhesions may complicate successful completion of robotic surgery [34]. A recent study evaluated the effects on perioperative outcomes of previous abdominal surgery in patients undergoing RAPN via a transperitoneal approach [8]. A total of 95 patients were evaluated, 41 (43%) of whom had previous intra-abdominal surgery. Results of the study showed that RAPN via the transperitoneal approach is feasible in patients with a history of abdominal surgery. Although there was no increase in complications in patients undergoing RAPN, increases in WIT and estimated blood loss were observed [8]. A recent comparative study of 660 patients undergoing partial nephrectomy found that within the relatively strict parameters of conventional practice, WIT duration was one of the only variables that the surgeon actually had control over, and therefore, efforts should be taken to minimize it [32]. Instead, non-modifiable patient factors such as the patient's preoperative renal function and the amount of parenchyma spared, are suggested to be the main determining factors in functional outcomes after partial nephrectomy [4,32]. The most recent and largest multi-institutional comparative analysis of consecutively performed RAPN and LPN procedures shows significantly lower WIT for RAPN than for LPN [9].

If the risk of significant intra-abdominal adhesions is high, the retroperitoneal approach can be adopted as an alternative to the transperitoneal approach during RAPN. Although the retroperitoneal approach avoids intra-abdominal adhesions, the working space is limited and the ports have to be placed carefully to avoid the robotic arms from clashing externally [35]. Early and intermediate outcomes of RAPN show excellent oncological control [4].

CONCLUSIONS

Robot-assisted partial nephrectomy is a viable alternative to both open and laparoscopic approaches, offering excellent short-term outcomes and cancer control [26]. It is one of the fastest growing robotic procedures worldwide [11]. The procedure potentially offers selected patients the benefits of minimally invasive surgery who may otherwise have to have open surgery or a radical nephrectomy. The oncological outcomes and disease-free survival of partial nephrectomy have been found to be equivalent to those in open surgery or a radical nephrectomy in carefully selected patients [2,10].

The use of robotic assistance can also aid surgeons with limited laparoscopic training to make the transition towards a minimally invasive approach for partial nephrectomy [24]. Despite this, the use of robotics has several difficulties, the most obvious is the cost of installing and the maintaining the robotic system [36]. To further evaluate this evolving technique a prospective analysis, including direct comparison with open and LPN, is required.

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CONFLICT OF INTEREST

None declared.

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Abbreviations: **RAPN**, robot-assisted partial nephrectomy; **LPN**, laparoscopic partial nephrectomy.