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Early experience and operative technique of robotic-assisted partial nephrectomy

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Abstract

Background: The adoption of robotic-assisted partial nephrectomy (RAPN) is increasing in Australia; however, to date no Australian RAPN series has been reported. This paper describes a single-surgeon initial experience with RAPN and evaluates perioperative, pathological and oncological outcomes.
Methods: Data on the first 50 consecutive patients to undergo RAPN by a single surgeon were reviewed. Demographic, perioperative, tumour characteristics and Clavien complications were collected in addition to oncological follow-up and renal function monitoring.
Results: Mean age was 58.2 ± 10.4 years, body mass index was 28.8 ± 4.5 kg/m^2 and Charlson Co-morbidity Index was 4.6 ± 1.2. Tumour diameter was 31 ± 13 mm and RENAL score was 6.8 ± 1.5. Average total operative time was 151 ± 32.7 min, estimated blood loss was 171.1 ± 185.8 mL, warm ischaemia time was 17.8 ± 6.7 min and length of hospital stay was 3 ± 0.9 days. There were seven Clavien complications and no deaths. Estimated glomerular filtration rate did not decrease significantly post-operatively ($P = 0.8$); and there was 14.6% upstaging of chronic kidney disease scoring although no patient required dialysis. There were no positive malignant surgical margins, and to date no patient has evidence of disease recurrence. Of 50 patients, 54% had a minimum follow-up of 6 months and 28% had a minimum follow-up of 1 year.
Conclusion: We report the largest RAPN study in Australia or New Zealand to date. Initial results suggest that RAPN can be safely introduced into the Australian public and private health systems, and has been effective in oncologic control and renal function preservation.

Introduction

Renal cell carcinoma is the seventh most common cancer in Australia, with an incidence of 12.1/100 000 persons/year.[1] Nephron sparing surgery (NSS) has become the standard of care for most renal masses, as open partial nephrectomy (OPN) has been shown to produce equivalent oncological outcomes to radical nephrectomy with improved renal function.[2–4]

A laparoscopic approach has been developed (laparoscopic partial nephrectomy; LPN) that produces the same oncologic and renal function outcomes as OPN with reduced morbidity and shorter hospital stay.[5] However, it is considered technically difficult with a long learning curve, and studies have indicated that LPN can result in longer ischaemia times as well as increased post-operative complications.[6,7] The technical complexities associated with LPN may limit patient access to NSS.[8,9]

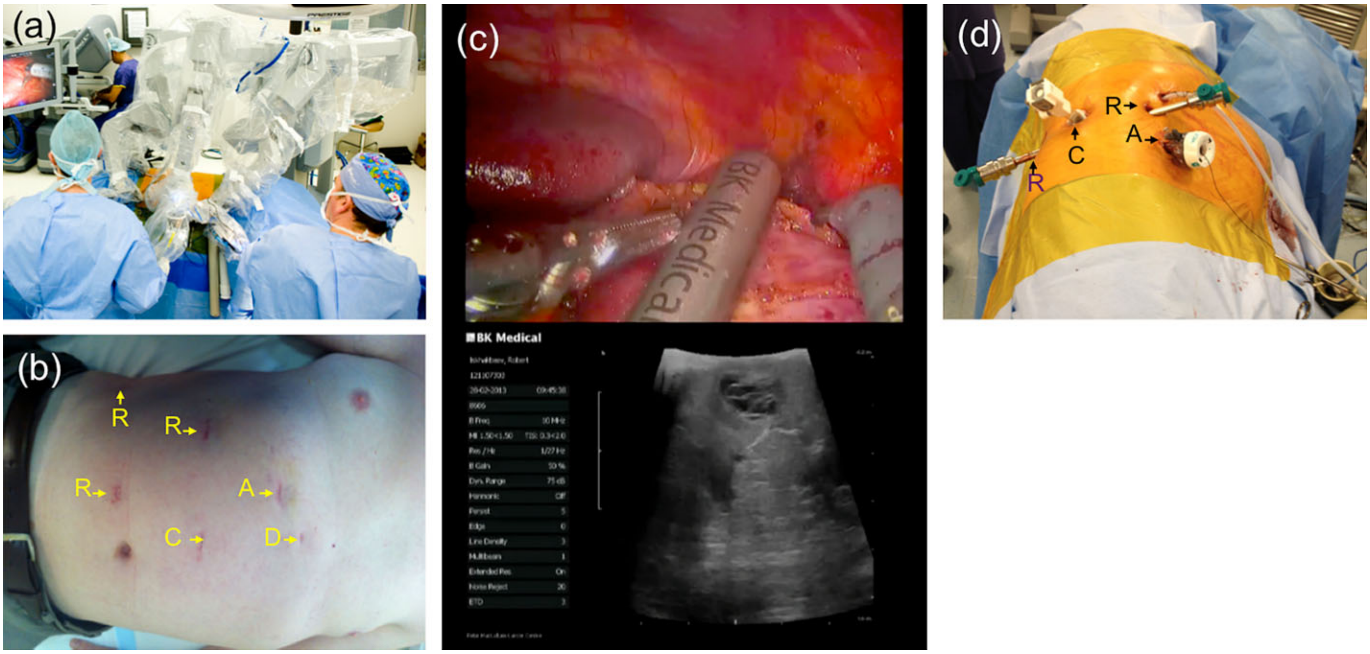

Fig. 1. (a) Robot docked for transperitoneal approach to the right side, patient's head is to the right and feet to the left; (b) operation wounds indicating port site placement for transperitoneal approach with fourth arm in the lateral position. A, assistant port; C, camera port; D, drain tube site; R, robotic trocar. (c) Console screen shot demonstrating intraoperative use of the TilePro feature to display the margins of an endophytic tumour; (d) port placement for retroperitoneal approach.

Robotic surgery confers multiple advantages, such as magnified three-dimensional viewing, superior instrumentation and ergonomic benefits that have made it well suited for NSS.[10] Although its use has been adopted relatively recently, reports on robotic-assisted partial nephrectomy (RAPN) suggest that it produces fewer positive surgical margins, shorter warm ischaemia time (WIT) and allows dissection of more complex tumours when compared with LPN.[11,12] RAPN is also believed to have a friendlier learning curve, which accounts for its quick adoption in many healthcare systems.[11,13] The first RAPN in Australia was performed in 2003, and there are currently 16 Australian institutions using the robotic approach.

RAPN has become an increasingly common treatment for small renal masses internationally; however, to date there have not been any reports of its adoption in Australia. To that end, we retrospectively analyse a single-surgeon experience with RAPN in both the Australian public and private sectors.

Methods

Outcomes of the first 50 patients to undergo RAPN performed by a single surgeon (DM) were reviewed, with data on all collected and recorded prospectively. Following a dedicated laparoscopic fellowship, surgical experience prior to commencing RAPN included 85 robotic prostatectomies, 170 laparoscopic nephrectomies and 30 LPNs. Surgery was performed across three Melbourne-based institutions, between November 2010 and November 2013. All patients underwent three-dimensional computed tomography (CT) prior to surgery to determine tumour characteristics and RENAL nephrometry score.[14] Preoperative parameters, including age, gender, body mass index, American Society of Anaesthesiologists score, tumour characteristics, haemoglobin (g/L), creatinine (μmol/L) and estimated glomerular filtration rate (eGFR, mL/min/1.73 m^2) were recorded. Post-operative complications to 90 days were graded according to the Clavien-Dindo score.[15]

Surgical procedure

Patients underwent general anaesthesia and then placed in the lateral position with 20 degrees of lateral flexion. All cases were performed on a da Vinci S HD four-arm system and a da Vinci Si system (Intuitive Surgical, Sunnyvale, CA, USA), neither of which had Firefly (fluorescence enhanced visualization) capability. The Hasson technique was used to gain access lateral to the umbilicus and three 12-mm trocars was placed in a wide 'V' configuration with adjustments laterally and superiorly for upper-pole tumours. An additional 10-mm trocar is placed in the contralateral quadrant for the assistant, with the port configuration as described by Benway *et al*.[16] The robot was docked in the configuration shown in Figure 1a.

A change in surgical technique occurred in February 2012 with the fourth robotic arm being moved from a medial to lateral approach to maximize intra-abdominal space and instrument dexterity. This reduced external collisions, particularly relating to the fourth arm, which could then retract the kidney for easier hilar dissection (Fig. 1b). Predominantly, a transperitoneal approach was used with five cases performed retroperitoneally for posteriorly placed tumours (Fig. 1d). In these cases, a dissection balloon was used under laparoscopic vision to create a workspace, the robot docked over the patients head, and the fourth arm omitted.

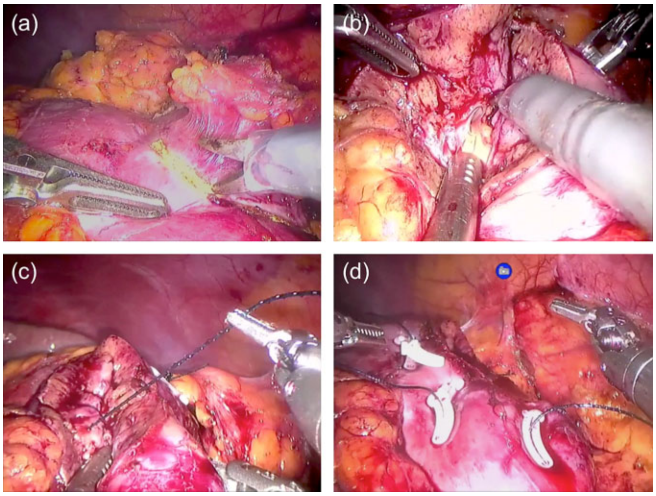

Fig. 2. (a) Cauterizing of renal capsule to mark resection margin; (b) identification of tissue and sinus structures to ensure a clear margin; (c) V-lok or monocryl suturing of deep layer/collecting system; (d) sliding clip renorrhaphy.

For a transperitoneal approach, dissection involved reflection of the hepatic or splenic flexure, and on the right, kocherization of the duodenum, for exposure of the renal hilum. Preoperative CT-angiography was critical in order to anticipate the arterial anatomy and plan the dissection. Once the renal artery and vein were identified and exposed sufficiently for clamping, the perinephric fascia was dissected from the kidney to expose the tumour. Mobilization of the kidney sufficient to visualize the entire circumference of the tumour was required.

Intraoperative ultrasonography utilizing the TilePro feature of the da Vinci system was used for all cases to define the deep and lateral tumour margins (Fig. 1c) and the renal capsule scored with cautery to outline the resection margin of the tumour (Fig. 2a).

Mannitol (25 g/m) was administered intravenously by the anaesthetist approximately 30 min prior to clamping. No patient required cooling of the kidney. A laparoscopic vascular bulldog clamp was used to occlude the renal artery only except in tumours involving the renal sinus, where the renal vein was also separately occluded.

Once the renal artery was clamped, the tumour was excised with cold cutting to a depth required for an adequate margin around the tumour as guided by preoperative imaging and intraoperative ultrasonography. The highly magnified vision afforded by robotic surgery in a bloodless field allowed very precise identification of cortical and medullary tissue then sinus structures to also ensure a clear margin around the tumour (Fig. 2b). Once excised, a deep V-lok or monocryl suture was used to close the deep layer/collecting system (Fig. 2c), then a sliding clip renorrhaphy performed using 0-vicryl sutures (Fig. 2d).[17] The renal hilum was then unclamped, further sutures placed as needed, then a 20 Fr Blake drain was placed through the most inferior and lateral trocar site.

Post-operatively, patients were mobilized and resumed diet within 24 h. On day one, serum haemoglobin, creatinine and eGFR were measured and the catheter was removed, then the drain was removed in day two. Patients were discharged when comfortable, reviewed again at approximately 2 weeks, then again at the 6-month mark with a repeat CT and renal function assessment. Further surveillance proceeded accordingly depending on the final tumour histology.

Statistical analysis

Continuous variables were reported as the mean plus or minus standard deviation. Comparative analysis was performed using a Mann–Whitney *U*-test, and correlations were performed using Spearman rank correlation. SPSS (IBM, Armonk, NY, USA) was used for both analyses. Statistical significance was considered at $P < 0.05$.

Results

Patient demographics and preoperative data

In this study, 50 patients underwent 51 procedures across three institutions between November 2010 and November 2013. One patient had bilateral tumours that were excised on separate occasions. The mean patient age was 58.2 ± 10.4 years, body mass index was 28.8 ± 4.5 kg/m^2 and Charlson Co-morbidity Index was 4.6 ± 1.2 (Table 1).

There was one patient (2%) with multiple tumours, which were excised during one procedure. The mean tumour diameter was 31 ± 13 mm and five (9.8%) tumours were hilar masses. The mean tumour nephrometry score was 6.8 ± 1.5, with 34 (66.7%) having moderate complexity and three (5.9%) having high complexity.

Perioperative data

One out of the 51 cases in this study case was converted to an open procedure because of an inability to access a left posterior upper pole tumour early in the series; no cases were converted to laparoscopy and five (10%) involved a retroperitoneal approach. The average total operative time was 151 ± 32.7 min with an estimated blood loss of 171.1 ± 185.8 mL (Table 1). The mean length of hospital stay was 3 ± 0.9 days, with one patient staying 6 days after conversion to an open procedure.

The average WIT was 17.8 ± 6.7 min. There were two cases in which WIT exceeded 30 min; one in which multiple ipsilateral tumours were removed (32 min) and one in which a branch of the renal vein required repair during renorrhaphy after removal of a deep hilar tumour (50 min, Fig. 3a). This operation was complicated by the location of the tumour and the co-morbidity of ankylosing spondylitis that affected patient positioning. Furthermore, the patient had presented with bilateral renal cell carcinoma therefore clearly all efforts were made to preserve both kidneys. Despite the prolonged WIT at 6 months post-operatively, the kidney enhanced normally on CT and at a follow-up of 12 months eGFR remains >90 mL/min per 1.73 m^2. Patients requiring collecting system repair had a mean WIT of 19.1 ± 7.5 min (range: 11–50), while those not requiring repair had a WIT of 15.7 ± 4.7 min (range: 6–26).

Tumour RENAL score correlated positively with WIT ($P < 0.001$), but did not with operative time or estimated blood loss ($P = 0.07$ and $P = 0.5$, respectively). Tumour diameter correlated positively with operative time, WIT and estimated blood loss ($P = 0.01$, $P < 0.001$ and $P = 0.007$, respectively).

Seven Clavien complications occurred. One patient required blood transfusion (Clavien 2) and radiologically guided

Table 1 Patient demographics, preoperative data and perioperative outcomes

Variable	Value
Total cases	51
Age (years), mean (SD; range)	58.2 (10.4; 28–75)
Sex, male	28 (62.2%)
BMI (kg/m^2), mean (range)	28.8 (18–42)
ASA, mean (SD)	2 (0.68)
Co-morbidities	
CCI, mean (SD)	4.5 (1.2)
Hypertension	24 (47.1%)
Diabetes mellitus	5 (9.8%)
Previous abdominal surgery	13 (25.5%)
Total number lesions	52
Laterality	
Right	29 (56.9%)
Site	
Upper	8 (17.4%)
Mid	20 (43.5%)
Lower	17 (37%)
Diameter (mm), mean (SD; range)	31 (13; 10–55)
Cystic component	9 (17.6%)
RENAL score	
Low [4–6]	15 (29.4%)
Moderate [7–9]	34 (66.7%)
High [10–12]	3 (5.9%)
Mean (SD; range)	6.8 (1.5; 4–10)
Operative time (min), mean (SD; range)	151 (32.7; 100–240)
WIT (min), mean (SD; range)	17.8 (6.7; 6–50)
EBL (mL), mean (SD; range)	171.1 (185.8; 20–1050)
LOS (days), mean (range)	3 (2–6)
Blood transfusion	1 (2%)
Conversion to open	1 (2%)
Post-operative complications	6 (12%)
Clavien-Dindo grade	
Grade 1	0
Grade 2	2
Grade 3a	1
Grade 3b	2
Grade 4	1

ASA, American Society of Anaesthesiologists; BMI, body mass index; CCI, Charlson Co-morbidity Index; RENAL, radius endophytic/exophytic properties, nearness of tumour to collecting system, Anterior/posterior location relative to polar lines; SD, standard deviation; EBL, estimated blood loss; LOS, length of stay; WIT, warm ischaemia time.

embolization (Clavien 3a) for ongoing haematuria, while two others were readmitted for haematuria and renal colic, requiring stent placement (Clavien 3b). One patient with premorbid cardiovascular risk was placed in intensive care because of a myocardial infarction and was transferred to a private hospital with no further serious sequelae (Clavien 4). Minor complications included fever and urinary tract infection, both requiring antibiotics (Clavien 2).

Laboratory data

Both serum creatinine and eGFR did not decrease significantly within 24 h of operation ($P = 0.7$ and $P = 0.8$, respectively). Preoperative chronic kidney disease stages are shown in Table 2, seven patients underwent upstaging postoperatively although none increased two or more stages. Tumour RENAL score was found to correlate positively with eGFR decrease ($P = 0.03$), interestingly tumour diameter did not ($P = 0.4$).

Pathological and oncological data

Pathological data were available for 51 cases, of which 43 tumours had malignant histology and eight benign (Table 3). A majority of

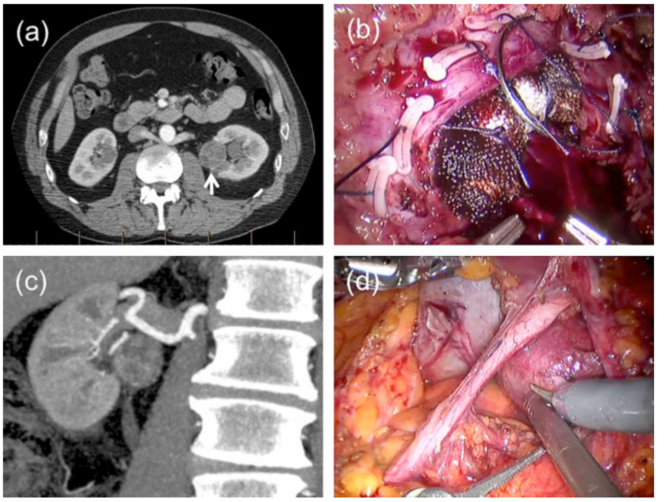

Fig. 3. (a) Computerized tomography section demonstrating a left posterior hilar tumour (arrow) that was removed during an extended warm ischaemia time (50 min). This was the second of staged bilateral robotic-assisted partial nephrectomy (note contralateral endophytic tumour). (b) Computed tomography demonstrating a hilar tumour; (c) dissection of a difficult hilar tumour; (d) closure of a hilar tumour.

Table 2 Pre- and post-operative laboratory values associated with robot-assisted partial nephrectomies

Variable	Preoperative value	Post-operative value
Haemoglobin (g/L), mean (SD)	141.5 (13.3)	123.0 (11.6)
Creatinine (μmol/L), mean (SD)	82.7 (20.6)	86.4 (25.2)
eGFR (mL/min per 1.73 m^2), mean (SD)	84.4 (20.8)	82.2 (23.0)
CKD		
Stage 1	6 (12%)	5 (11%)
Stage 2	39 (78%)	32 (68%)
Stage 3	5 (10%)	11 (23%)
Stage 4	0 (0%)	0 (0%)
CKD stage diminution	7 (14.6%)	

CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate; SD, standard deviation.

the malignant tumours were clear cell carcinomas ($n = 31$); papillary, chromophobe, tubulocystic and cystic were also excised ($n = 5$, 3, 1 and 2, respectively). One pT3 tumour was excised with negative surgical margins, and no recurrence of disease has been detected to date. Both patients with positive surgical margins had benign masses, one was found to be an angiomyolipoma while the other was an oncocytoma (Table 3). Neither patient has demonstrated evidence of disease recurrence at 23 months and 1-month follow-up, respectively.

Due to the relatively recent onset of this study, 47% of patients have not had their 6-month follow-up, while 14 (29%) have a minimum follow-up of 1 year.

Discussion

NSS has been increasingly encouraged for patients with small renal masses as the importance of maximizing kidney function has been

Table 3 Pathological and post-operative outcomes after robot-assisted partial nephrectomies

Variable	Value
Size tumour (mm), mean (SD; range)	27.1 (11.7; 7–55)
Positive margin rate	
Malignant	0 (0%)
Total	2 (3.9%)
Histology	
Malignant	43 (84.3%)
Benign	8 (15.7%)
Malignant histology	
Clear cell	31 (73.8%)
Papillary	5 (11.9%)
Chromophobe	3 (7.1%)
Tubulocystic	1 (2.4%)
Cystic	2 (4.8%)
Benign histology	
Angiomyolipoma	2 (25%)
Oncocytoma	6 (75%)
T stage	
pT1a	37 (74%)
pT1b	12 (24%)
pT2	0 (0%)
pT3	1 (2%)
Oncological recurrence	0
Length of stay (days), mean (SD; range)	3 (0.9; 0–6)
Follow-up (months), mean (SD; range)	6.1 (7.2; 0.01–30.5)

SD, standard deviation.

appreciated.[18] OPN accomplishes this goal, as does LPN, while additionally decreasing patient convalescence. However, LPN can generally only be performed by experienced laparoscopic surgeons, which some believe has led to its underutilization.[19]

RAPN has been shown to offer a shorter learning curve while accomplishing comparable oncological and renal function outcomes to LPN and OPN.[19–21] Furthermore, as we have experienced, robotic assistance has been shown to allow removal of larger or more complex masses than are typically attempted laparoscopically.[22,23] For these reasons, it is preferred over LPN in many healthcare systems. The shortened learning curve and increased number of eligible patients are advantages of RAPN that may increase access to NSS.[24]

The effect of WIT on preserving renal function is a subject of disagreement; however, most studies indicate that a WIT under 30 min is ideal.[25–27] For the 51 cases in this study, the mean WIT was 17.8 ± 6.7 min, which is equivalent or shorter than other RAPN series reviews.[11,13,19,20,28] In tumours greater than 4 cm in diameter, our mean WIT was 21.4 ± 8.4 min, which demonstrates the ability to excise larger tumours via robotic assistance without a potentially dangerous increase in WIT.[29]

Despite high weighted co-morbidities and RENAL scores, our complication rate (11.8%) compared favourably with many RAPN reports, including a large RAPN series by Kalifeh *et al.* (18.7%).[11,20,28] This speaks to the surgeon's laparoscopic experience before initiating the robotic approach, as well as the short learning curve which has been previously established.[30]

In terms of renal function, seven patients had upstaging of their chronic kidney disease score post-operatively, with a non-significant decrease in eGFR of only 2.2%. Due to the recent onset of this study, limited 6-month post-operative renal function data were available, however, only one (5.5%) patient demonstrated chronic kidney disease upstaging, with no significant decrease in eGFR at 6 months post-operation. RENAL nephrometry scores have been suggested to be associated with increased post-operative renal function deficits.[31] However, there was no correlation in our series.

As this report represents an initial experience with RAPN, initially less complex tumours were resected. With more experience, increasingly complex tumours were excised without an increase in complication rate, WIT or operation time (Fig. 3b,c,d). In large LPN series, tumour complexity was found to positively correlate with operative time;[32] however, there was not an association in our RAPN series. This perhaps indicates that RAPN can offer a more uniform experience and shorter learning curve.

Finally, there were no surgical margins positive for malignancy, nor any malignant recurrences in this series; both cases with positive surgical margins were of benign masses.

The adoption of RAPN in Australia has been relatively limited, perhaps due to the prohibitive nature of the initial cost of robotic surgery. However, recent cost analyses have shown that the reduced length of stay afforded by RAPN compensate for the expense of the robot when compared with OPN.[33] Although RAPN is more expensive than LPN, it has been suggested that costs are comparable when comparing cases of equivalent RENAL scores.[34]

The primary limitation of this study is the sample size and length of follow-up; however, we feel it is important to present early results of new surgical techniques. Therefore, limited 6 months and longer-term follow-up data were available. As factors such as tumour characteristics, renal function and patient co-morbidities influence the decision to pursue NSS; our report is also subject to selection bias. However, we believe this is not unique to this study.

Conclusion

To our knowledge, this is the first report of RAPN in Australia. Our perioperative, renal function and oncological outcomes are comparable with what has been achieved internationally, and suggest that RAPN can be a safe technique for NSS in the Australian public and private setting. Continued patient follow-up can provide more concrete evidence of the effectiveness of RAPN with respect to oncological and renal outcomes.

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