CHALLENGING SITUATIONS IN PARTIAL NEPHRECTOMY

Abstract

Although most partial nephrectomies are performed as primary procedures in the elective or semi-imperative setting on kidneys with relatively normal anatomy, this is not always the case.

The indications for partial nephrectomy continue to expand and it is becoming particularly relevant in patients with single functioning kidneys, poor kidney function, anatomical anomalies and hereditary syndromes predisposing to multiple kidney cancers, such as Von Hippel-Lindau syndrome. These, along with previous abdominal surgery, pose surgical challenges. In this article we offer advice as to how to tackle these unusual situations.

An ability to master the whole range of indications will allow the modern upper renal tract surgeon to offer partial nephrectomy to a wider range of patients.

Challenging Situations in Partial Nephrectomy

The growing detection of asymptomatic small renal masses has resulted in a significant stage migration of RCC[1]. Greater recognition of the importance of preservation of renal function alongside cancer control has further shifted treatment towards nephron sparing techniques. For T1 tumours in healthy patients, partial nephrectomy is now considered the standard treatment. Superior functional and equivalent oncological outcomes mean it is favoured over radical surgery for both T1a and T1b when feasible[2]. The development and increasing use of minimally invasive techniques continue to extend these indications even in those patients previously considered too complex or technically difficult. The key challenging situations a renal surgeon may face are outlined in this article together with advice on how these particular circumstances should be handled.

Prior Abdominal Surgery

Prior abdominal surgery can present a difficult situation for the robotic surgeon. It has been shown to increase the risk of intra-abdominal adhesions making access difficult or even impossible[3]. Patients need to be consented appropriately and understand the increased risk of conversion to open surgery and injury to vascular or visceral structures in particularly to bowel. Prior abdominal surgery has been shown to be associated with increased operative times and complication rates during laparoscopic surgery[4,5].

Thorough preoperative planning involving the whole surgical team is vital. Understanding exactly what previous surgery was performed, the technique and indication is paramount. For example large bowel operations, ruptured appendix and inflammatory bowel diseases are more likely to cause greater adhesions[6].

In difficult cases it is sensible to choose the most experienced nursing staff and assistant for such cases. A reliable, familiar team who understands the intricacies of robotic surgery and can troubleshoot unexpected problems is very important in these situations.

The next step is to decide on which approach to take. A retroperitoneal approach may be more suited if the patient has had prior intra-peritoneal abdominal surgery, particularly when faced with posterior renal tumours. Its disadvantages are the lack of space and that it is often a less familiar approach for the surgeon. Camera port placement allows the surgeon to assess the amount of adhesions and whether the remaining ports can be inserted safely.

Several techniques can be used to gain access. No device or technique is perfectly safe and there is no consensus regarding the optimal choice, although if in doubt, the open Hassan technique is likely to be safer than a blind Veress needle insertion. If using a Veress needle technique, it should be inserted at a distant site to previous incisions. Optical trocars are not recommended in these situations due to increased risks of bowel injury.

The remaining instrument ports are then triangulated. Knowledge of optimal distances is important to prevent the robotic arms from clashing. Ports need to be at least 8 cm apart and 10-20cm from the target anatomy when using the da Vinci Si. With the new Da Vinci Xi, ports can be as close as 6 cm. Tapping the skin at the intended insertion site helps the surgeon to visually determine if it is safe to place a trocar. If unsure, a spinal needle can be inserted through the skin and its trajectory can be followed with the camera to ensure there is no interposed bowel. An advantage of the Xi is that the camera can be inserted through any of the robotic ports, allowing the surgeon to visualize the insertion of other ports from different angles. This is particularly useful when placing the assistant ports in the presence of intra-peritoneal adhesions.

Adhesiolysis with laparoscopic scissors may be required to allow safe placement of additional robotic ports after placement of initial trocar. It may be easier to dock one robotic arm first and use the robotic scissors to safely divide adhesions before docking the remaining arms.

A recent study on previous abdominal surgery (PAS) and robotic partial nephrectomy retrospectively analysed 1686 patients who had undergone RPN from an American multi-centre prospective database from 5 large academic institutions[7]. A sub-group of 216 patients (13%) had undergone "major previous abdominal surgery" (PAS); defined as those marked by upper midline or ipsilateral incisions. The list of prior surgeries is wide ranging with 12% (n=25) having multiple previous procedures and many others having laparotomies, open cholecystectomies and open ipsilateral partial nephrectomies. 11% had a retroperitoneal approach in the PAS group compared with 5.4% in the control arm.

The study found that there was no difference between intraoperative and post-operative complications (<4% Clavien ≥3 in PAS group), positive surgical margins and change in renal function. Their initial concern that previous surgery increases robotic operative time was ill founded as there was no statistical difference in median operative times (PAS 172mins (132-224) vs no PAS169mins (139-208)). However, they did find statistical difference in estimated blood loss, which was higher in the PAS group (150ml vs 100ml p=0.039), but this did not translate to a difference in transfusion rates.

They also found the PAS patients were older (median 63 vs 60years) and had a higher median BMI (30.3 vs 29). This is an important finding in the context of offering robotic minimally invasive surgery in an increasingly obese and ageing surgical population.

Another study on transperitoneal robotic partial nephrectomy showed that patients with prior abdominal surgery were more likely to require adhesiolysis (41% vs 15%, P = 0.005). Adhesiolysis took a mean time of 32 min but there was no statistical difference in overall operative time however. In the prior abdominal surgery group, there was a trend toward longer median warm ischaemia time (21 vs 16 min) and median estimated blood loss (150 vs 100 ml), without reaching statistical significance. There was no significant difference in intra or post operative complications[3]. Transperitoneal robotic partial nephrectomy therefore is feasible in the setting of prior abdominal surgery.

Single Functional Kidney

One of the most common challenging situations a renal surgeon will encounter is that of the patient with the single functioning kidney. Close attention needs to be taken to manage the discordant risks of renal cancer and chronic renal failure with its attendant cardiovascular risk and increased mortality[8]. The two primary aims are to achieve adequate tumour resection whilst maintaining sufficient renal function. Chronic kidney disease is encountered in a large proportion of patients with small renal masses[9], but the significantly lower preoperative estimated glomerular filtration rate (eGFR) of patients with solitary kidneys highlights their vulnerability[10]. A single functioning kidney is one of the most significant risk factors for developing renal failure following nephron sparing surgery (NSS)[11].

Partial nephrectomy, despite the risks, is a feasible management option but the factors affecting post operative eGFR remain under debate[10,12-14]. La Rochelle et al found that the only relevant variables were cold ischaemia time and the presence of cardiovascular risk factors[12]. Furthermore these factors only affected immediate post-operative renal function; none were associated with long-term eGFR. The lack of effect of tumour size was also reported in another single centre study however the authors did show that clamp time and blood loss were significant predictors of post operative eGFR[10]. Again no factors were found to impact the long-term eGFR. Concerns regarding prolonged ischaemia remain valid in the immediate post operative especially in the setting of preoperative renal impairment[15-18]. However large studies have found that in the long term, ultimate renal function is primarily determined by the amount of parenchymal loss not the degree of ischaemia injury[13,16]. After an initial post operative fall in eGFR, studies have shown that long term renal function remains relatively stable following partial nephrectomy[10,12,13]. Thankfully the need long term dialysis remains uncommon[12-14,19]. Those patients with lower preoperative eGFR are at a greater risk of end stage renal disease (ESRD)[12].

Oncological safety is paramount in NSS on solitary kidneys. Given the bleak outcomes for patients on dialysis, avoiding radical nephrectomy is vital[20]. The most significant risk factors to developing ESRD are inadequate resection and local recurrence[13]. Positive surgical margin (PSM) rates have been found to be higher in solitary kidney patients compared to patients with normal contralateral kidneys but its significance is contentious. There is evidence to suggest that PSM have negligible effects on development of metastasis[21] whilst other authors argue that PSM do increase the risk of metastasis[22]. As a result although it is argued that tumour enucleation can offer equivalent outcomes as partial nephrectomy, the balance appears to be moving in favour of performing an adequate resection to minimise the risk of a PSM[23].

Overall NSS in solitary kidneys has been shown to be effective with 5 year cancer specific survival rates of 77.5-95.1% (table 1). Given survival rates of dialysis patients are less than half, it can be argued that NSS is imperative in appropriate patients in the setting of a single functioning kidney[20]. CSS rates are comparable to patients with a normal contralateral kidney and lower overall survival rates in solitary kidney patients attributed to the morbidity of CKD[14,24].

Historically an open rather than laparoscopic approach was associated with better post operative renal function[25]. LPN has been shown to be safe and effective, but success remains dependent both on patient selection and the surgeon's laparoscopic expertise[26]. In open approaches ice slush cooling is usually utilised in such cases whilst minimally invasive approaches often employ early unclamping or segmental clamping techniques to minimise renal ischaemia. Recently a robotic assisted ice slush cooling technique has been published which may allow more single kidneys to be treated minimally invasively[27]. Whilst it remains an advanced procedure, the benefits of the robotic platform help overcome a number of the difficulties faced in partial nephrectomy[28]. Precise tumour resection and a faster renorrhaphy help reduce renal injury.

As with 'routine' small renal masses, thermal ablation (TA) offers an alternative treatment option. Given the scarcity of cases, data on experience and outcomes for TA in solitary kidneys remains limited.

Analysis of available observational data shows that whilst PN offers better cancer control, TA is associated with better preservation of renal function and lower complications, thereby offering a viable option for those patients with increased co-morbidity or otherwise unsuitable to undergo PN[29].

Von Hippel-Lindau Syndrome

Von Hippel-Lindau (VHL) syndrome is the most common hereditary renal cell carcinoma (RCC) syndrome. Inherited in an autosomal dominant fashion, loss of the VHL gene leads to the accumulation and over expression of hypoxia inducible factor 1 (HIF-1) and consequently tumour formation. Amongst the various clinical manifestations, renal cell carcinoma is one of the most common and a leading cause of mortality[30]. Surgical management of hereditary, multifocal tumours such as VHL focuses on preventing metastatic disease whilst maintaining native renal function for as long as possible. Effective screening is an essential component of management starting with annual ultrasounds during childhood before progressing to yearly contrast enhanced CT scans from 18 years[31]. Historically patients with multifocal and recurrent hereditary tumours were managed with bilateral nephrectomy and dialysis with a view to transplantation. However developments in nephron sparing surgery together with shortages of donor organs and recognition of the morbidity of even short periods of dialysis has lead to the development of new surgical approaches.

Managing VHL patients with small renal masses centres on accurate diagnosis. When possible renal biopsy should be performed to provide a histological diagnosis as well as for genetic testing[32]. Split renal function needs to be assessed to establish baseline renal function and guide subsequent treatment.

Surgical intervention requires careful consideration to minimise renal tissue loss. In this setting bilateral partial nephrectomies are indicated and may be performed either as a staged procedure or simultaneously, the latter becoming increasingly common. If a staged strategy is used, the largest tumour is usually resected first given the greater risk of metastasis[33]. On the other hand some surgeons elect to operate on less complicated tumour first. Laparoscopic and robotic techniques have been shown to be feasible in treating multiple renal tumours however their use must not come at the expense of oncological clearance[34,35].

When planning surgery, the 3cm rule is often applied to hereditary renal cell carcinomas. Developed for VHL patients, it dictates that only solid tumours over 3cm are treated as compromise between oncological safety and nephron preservation and to delay surgery and potential dialysis as long as possible[33,36]. Given the negligible effects of a positive margin in such small renal masses together with the need to maximise residual renal parenchyma, enucleation is considered a safe and sensible technique[37,38]. Patients are highly likely to require further surgery so liberal renal hilar dissection and vascular clamping needs careful consideration. Many surgeons favour non-ischaemic dissection to reduce ischaemic injury but competent assistance during dissection is crucial for maintaining a clear surgical field. Larger bleeding vessels should be individually sutured whilst smaller vessels and generalised bleeding managed with haemostatic agents. Avoiding non-specific cautery especially at the base of the defect helps protect segmental vascular supply. Minimising dissection of the kidney and preservation of Gerota's fascia with a clam shell incision can help reduce adhesions, adherence of the kidney to the abdominal wall, and the chance of fistula formation between multiple defects[32]. It is also advised to replace Gerota's fascia around the kidney on closure to reduce scarring. If revision surgery is then required at a later stage, these authors recommend altering the approach. If an open flank incision were made, then a transperitoneal approach would be recommend. Likewise following a primary laparoscopic or robotic transperitoneal partial nephrectomy, retroperitoneal revision surgery should be considered.

Ablative techniques are increasingly being used for treating VHL, particularly smaller, recurrent tumours. Ablation allows repeated interventions with greater preservation of renal function compared to NSS. Both cryotherapy and radiofrequency ablation (RFA) have been used effectively in treating VHL patients[39,40] and combined with PN[41].

Careful, targeted management of hereditary RCC syndromes such as VHL has been supported by various studies. Herring et al reported their 10 year experience of managing 50 patients none of whom required dialysis and only one developed metastatic disease[42]. Roupert and Walther et al reported similarly good results with no metastatic progression[36,43].

Horseshoe Kidney

There are a few reported cases of robotic surgery performed for small renal masses in horseshoe kidneys. With an incidence rate of 1 in 400 and a 2:1 ratio in men, horseshoe kidneys are the most common renal fusion anomaly. They appear more often with chromosomal aneuploidies (trisomies and Turner syndrome)[44]. Fusion of the inferior portion of the metanephric blastema during the sixth week of gestations forms the isthmus. As a result, renal ascent is limited by the inferior mesenteric artery at the level of L3.

As a consequence, the kidneys have medially facing lower pole calyces, malrotation with calyces facing more posteriorly and the renal pelvis more anteriorly. Vascular supply is commonly atypical with renal vessels arising from any of the aorta, inferior mesenteric artery (IMA), iliac vessels or even sacral artery. Multiple renal arteries are found in 70% of horseshoe kidneys. An artery to the isthmus is common; 65% originate from the aorta and 35% from the IMA, main renal artery or iliac vessels[45]. The isthmus commonly lies anterior to the aorta and vena cava but rarely may pass between the inferior vena cava and the aorta or even behind both great vessels.

Horseshoe kidneys may also have a high ureteric insertion and the course of the ureters is anterior to the isthmus and lateral to lower pole calyces, which is a key intravenous pyelogram (IVP) finding.

Although most horseshoe kidneys are asymptomatic, complications can include pelviureteric junction obstruction (up to 30%), renal calculi, urinary tract infections, vesicoureteric reflux (up to 50%) and a twofold risk of Wilms tumour[46]. Rates of other renal tumours are comparable to the general population. Renal cell cancer accounts for 45% of malignant lesions in horseshoe kidneys while Wilms' tumour accounts for 28%[47]. Transitional cell cancer and sarcoma account for 20% and 7% of tumours, respectively[45,47].

Robotic oncologic surgery in patients with horseshoe kidneys can be technically challenging due to the aberrant anatomy. Adequate preoperative imaging is crucial. A triple phase CT or MRI with three-dimensional arterial reconstruction is strongly encouraged.

A skilled bedside assistant with suitable laparoscopic experience is important to ensure safe application of clips and staples through a standard laparoscopic technique[48].

A robotic partial nephrectomy or heminephrectomy in a horseshoe kidney can be performed using a transperitoneal or a retroperitoneal approach. The latter may be essential for posterior tumour as a horseshoe kidney does not allow traditional mobilization and flipping of the kidney[49].

For a transperitoneal approach, the positioning of the patient is similar to that used in a standard robotic partial nephrectomy, with the patient in a flank position. The ports however need to be adjusted to be slightly more medial and caudal. A fourth robotic arm is recommended for retraction.

The colon is reflected to expose the aorta and IVC. The ureter and the renal pedicle are then carefully dissected. Anomalous arterial branches are identified and dissected out in preparation for hilar clamping. In a horseshoe kidney, most of the vessels are above the isthmus[47]. After tumour excision, reconstruction can be performed using standard running 3-0 monocryl and interrupted 0-Vicryl sutures for the parenchyma and capsule, respectively. It should be noted that even after clamping, the kidney is still supplied by the other moiety. This can make dissection very challenging, but it does reduce the risk of ischaemic renal injury.

If a heminephrectomy is required, the kidney should be fully mobilized so that the isthmus can be divided. Several laparoscopic techniques have been described such as placing a Satinsky clamp on the isthmus prior to sharply dividing it and then running a 2-0 vicryl for parenchyma haemostasis[50], or clipping the isthmus with a 15-mm Hem-o-lok, dividing it with a Harmonic scalpel then tying a PDS Endoloop around the isthmus[47]. Or even transecting the renal isthmus using a laparoscopic stapler[48].

The challenging anatomic variations of horseshoe kidneys should be approached cautiously. It is recommended that such cases not be undertaken by novice and intermediate robotic surgeons. The few reported cases in the literature of robotic partial nephrectomy or heminephrectomy in a horseshoe kidney show that the procedure is feasible and safe in expert hands. However, meticulous attention to the patient's vascular anatomy via high quality vascular reconstruction CT imaging is paramount to avoid bleeding complications. Port placement needs to be individualized to avoid instrument clashing and to facilitate optimal access to the kidney[51].

Ectopic Pelvic Kidneys

Ectopic pelvic kidneys are uncommon, presenting in 1/10,000 patients whilst autopsy studies estimate their true prevalence as up to 1/1000[52]. With their short, torturous ureters pelvic kidneys are more susceptible to infection, calculi and obstruction. They do not confer an increased malignancy risk but cases of renal cell carcinoma in pelvic kidneys have been reported. Treatment should adhere to the general principles of oncological management although a number of aspects need careful consideration.

Laparoscopic surgery on pelvic kidneys is feasible with evidence from a number of case series[53-56]. The altered anatomy of the pelvic kidney poses a number of challenges to the surgeon. Firstly the kidney is usually buried deep within the pelvis below the aortic bifurcation and hidden by the sacrum if approaching from the abdomen. The ectopic position of the hilum and malrotation of the kidney make dissection especially within the confines of the pelvis[56]. Ectopic kidneys maybe associated with other anatomical abnormalities of the vertebral column, gastrointestinal and urogenital tract altering anatomy and complicating access[45]. Secondly the vasculature, dependent on the position of the kidney, is also liable to be highly variable[57]. The arterial supply may originate from the distal aorta, aortic bifurcation, common or external iliacs or even the inferior mesenteric vessels. Preoperative angiography is therefore recommended to help delineate the anomalous vasculature[55-57]. Nevertheless intraoperatively careful but extensive dissection is necessary to prevent inadvertent injury to major pelvic vessels and ureters[55].

Only a single case of a open partial nephrectomy in a pelvic kidney has been reported in the literature [58]. Aside from this, the literature in managing renal masses in pelvic kidneys is restricted to individual case reports of laparoscopic nephrectomies[54]. The rare issue of a renal tumour within a functioning transplant can occasionally occur[59]. As for other special situations high quality renal and vascular imaging is required. A open approach is generally needed with ice slush cooling or non-clamp techniques employed to minimise ischaemic damage. It is wise to pre-operatively stent the transplant ureter to minimise the risk of urine leak and to bear in mind the longer healing times required for patients on immunosuppression when managing these patients post- operatively.

Conclusions

With increasing numbers of patients undergoing partial nephrectomy, the occurrence of some of these special situations is increasing. Whilst the principles remain the same as the standard situations special attention should be paid to pre-operative imaging, multi-disciplinary discussions of all treatment options and referral to highly experienced teams if possible. Generally careful choice of approach and access is key in cases of prior surgery, warm ischaemia should be minimised in poorly functioning kidneys, and aberrant anatomy appreciated in anomalies of fusion and ascent.

As experience increases these special situations will increasingly become part of the repertoire of the kidney surgeon.

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Table 1 Outcomes for Partial Nephrectomy in Single Kidneys

Study	Date	Approach	Outcomes
Ghoneim et al[10]	2015	Open Partial Nephrectomy, n = 103	5 year OS = 64% 5 year CSS = 81%
Ching[13]	2013	Open Partial Nephrectomy, n = 282	5 year OS = 78.5% 5 year CSS = 95.1% 5 year RFS = 75.4% 10 year OS = 59.5% 10 year CSS = 91.9% 10 year RFS = 70.8%
Lee et al[19]	2011	Open Partial Nephrectomy, n=38	5 year OS = 59.6% 5 year CSS = 77.5% 5 year RFS = 45.7%
La Rochelle[12]	2009	Open Partial Nephrectomy, n = 68	5 year CSS = 89% (no prior metastatic disease)

Pahernik[60]	2007	Open Partial Nephrectomy, n = 103	5 year OS = 80.1% 5 year CSS = 89.6% 10 year OS = 54.1% 10 year CSS = 76%
Fergany[61]	2006	Open Partial Nephrectomy, n = 400	5 year OS = 87% 5 year CSS = 89% 10 year OS = 77% 10 year CSS = 82%
Saranchuk[14]	2004	Open Partial Nephrectomy, n = 54	5 year OS = 68% 5 year CSS = 88% 5 year RFS = 73%
Ghavamian et al[24]	2002	Open Enucleation, n = 23 Open Partial Nephrectomy, n = 24 Both = 7 Ex Vivo tumour resection = 8	5 year OS = 74.7% 5 year CSS = 80.7% 10 year OS = 45.8 10 year CSS = 63.7%

OSS: Overall Survival, RFS: Recurrence Free Survival, CSS: Cancer Specific Survival