

Minimally invasive nephron-sparing surgery for renal cell cancer

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INTRODUCTION

Nephron-sparing surgery (NSS) is now an established concept; building on the excellent outcomes of open partial nephrectomy (OPN) [1], considerable interest has recently focused on minimally invasive NSS (MINSS). Various techniques of MINSS are currently available: the greatest experience has been with laparoscopic PN (LPN), renal cryoablation and radiofrequency ablation (RFA). In their basic premise, all MINSS options strive to achieve the essential goal of OPN: excision or destruction of the renal tumour with a rim of healthy parenchyma, with durable functional and oncological outcomes. Increased experience and standardization of technique in the last 3–4 years have led to a reduction in procedural complication rates, despite the inclusion of more complex cases. Enthusiasm for elective MINSS has been fuelled by several factors, including a growing awareness of the natural history of the disease, sophisticated renal imaging, improved surgical techniques, and ultimately equivalent long-term cancer-free survival data [2–4]. In this review, we examine the principles of MINSS, the salient technical aspects of the procedures, the current results to date, and future concepts.

THE BASIS OF NSS

Indications for NSS can be divided into absolute, relative and elective [5]. Absolute indications are those in which radical nephrectomy for a localized tumour would render the patient anephric; these include tumours in solitary kidneys or bilateral synchronous renal tumours. Relative indications include a unilateral renal mass in the setting of perceived future threat to overall renal function due to local or systemic

factors. Examples include renal calculus disease, chronic pyelonephritis, diabetes mellitus, and Von Hippel–Lindau disease. Elective indications include a small (≤ 4 cm) renal tumour in the presence of a normal opposite kidney. Short-term disadvantages of open NSS include the morbidity of the open incision, greater blood loss, urine leak and potential for re-exploration (Table 1) [4,6–9], whilst in the long term there is a small risk of ipsilateral disease recurrence. Decisive factors in the elective setting include surgeon experience, size and position of tumour, comorbidity, and patient preference.

A tangible clinical benefit of retained ipsilateral renal tissue has yet to be confirmed, but data attesting to its theoretical importance are compelling [10]. In the presence of a normal functioning contralateral kidney, long-term renal dysfunction (defined as a serum creatinine level of >2 mg/dL) due to hyperfiltration injury was significantly higher at 10 years after radical nephrectomy than after PN (22% vs 12%, $P=0.01$) [11]. In addition, metachronous contralateral renal tumours can occur in a significant proportion (10%) of patients [5]. With the increasing incidence both in the USA and Europe [12,13] of small, asymptomatic, incidental lesions, $\approx 30\%$ of which are benign and/or indolent [2,14], the spectre of unnecessary nephron loss following nephrectomy is all too real.

MINIMALLY INVASIVE APPROACHES

Currently there are several MINSS techniques, i.e. LPN/wedge resection, cryotherapy, RFA and miscellaneous energy sources, e.g. intracavitary photon radiation, microwave thermotherapy, high-intensity focused ultrasound (HIFU), etc.

LPN

Currently LPN is the most widely reported MINSS technique, with >1000 cases

worldwide. Because it is technically demanding, it is performed in only a few centres, with fewer still having the experience to offer this for other than elective indications. By definition, clinical indications and mass characteristics should be similar to those for OPN. Whereas initial series described LPN in favourably located small peripheral exophytic tumours [15], reports from specialist centres now include series with tumour invasion deeply into the collecting system or renal sinus, completely intrarenal tumours, tumour substantial enough to require heminephrectomy, renal hilar tumours and tumours in solitary kidneys [16,17]. Current contraindications include previous open kidney surgery, the presence of concomitant renal vein thrombus, or an interpolar completely intrarenal tumour. Relative contraindications include patients with blood dyscrasia from uraemia, anticoagulants or antiplatelet therapy [18]. LPN should be offered only by surgeons with considerable experience in minimally invasive surgery and it is wise to restrict LPN early in the learning curve to polar or exophytic tumours, to minimize laparoscopic complications and conversion rates.

Meticulous preoperative imaging is essential to confirm the suitability of the patient and to reduce complications. Helical contrast CT with three-dimensional image post-processing is currently the technique of choice [19]. This gives reliable information on the position of the tumour with respect to adrenal, surrounding fat, parenchyma, collecting system and intrarenal extension into renal sinus. Arterial and venous anatomy and their interrelationships are accurately displayed.

Points of technique

Only salient features will be highlighted here. The surgical approach is determined primarily by the position of the tumour. The retroperitoneal approach is more challenging as the surgical field can be restricted,

TABLE 1 Complications after OPN

Study	No. of patients	Mortality	Urine leak	Abscess	Bleeding after OPN	Re-operation
Steinbach <i>et al.</i> [6]	140	2	3		2	2
Moll <i>et al.</i> [7]	164	0	11		6	1
Campbell <i>et al.</i> [8]	259	4	45	11	6	8
Lerner <i>et al.</i> [9]	169	1	3	1		3
Belldegrun <i>et al.</i> [4]	146	3	2		3	3
Total	878	10 (1)	64 (7)	12 (1)	17 (2)	17 (2)

resulting in suboptimal suturing angles. However, it provides better access to posterior and posteromedial tumours. All other tumours are approached transperitoneally. Both approaches are comparable in terms of blood loss, urine leak, postoperative complication rates and histological outcomes [20]. The hilar vessels are prepared for *en bloc* clamping (the vessels are not skeletonized in their entirety, as this is unnecessary for vascular clamping, might cause vasospasm, and risks iatrogenic injury). Gerota's fascia is incised and perirenal fat is removed except for the fat directly over the tumour. An intraoperative, steerable flexible ultrasound probe provides precise anatomical information of the tumour as regards depth, central extension, distance from renal sinus and collecting system, and as a guide for outlining the circumferential margin of surgical resection.

Haemostatic control

An efficient PN requires excellent visualization of the tumour bed, which in turn demands a bloodless operative field. This is obtained most reliably with hilar cross-clamping, resulting in renal ischaemia. Atraumatic *en bloc* clamping of the renal hilum is followed by cold excision of the lesion. Although this can be done quickly (4–5 min) with excellent vision of the surgical margins, the next step of collecting system and vascular suture-repair followed by parenchymal renorrhaphy requires time-sensitive and precise suturing to limit the warm ischaemia time. The time constraints this places on the surgeon has been likened to working 'under the gun' [18]. Experience in open surgery suggests that the recovery of renal function is usually complete within hours after 20 min of ischaemia, within 3–9 days after 30 min, within weeks after 60 min, and absent after 120 min [21]. Warm ischaemia times of up to 30 min during LPN

have been shown to be tolerated with no significant effect on serum creatinine levels [22]. In rare circumstances, such as multiple tumours in the same kidney or more anatomically complicated tumours, where a longer ischaemic time is anticipated, renal hypothermia may be used. Minimally invasive renal cooling during hilar occlusion can be achieved by three techniques: renal arterial perfusion (via percutaneous catheterization of the femoral artery) [23]; renal pelvic instillation of cold saline via a ureteric catheter [24]; or our preferred technique of surface contact slush-ice around the kidney enclosed within an entrapment sac [25].

For the smaller, completely exophytic tumour, wedge-resection techniques with no ischaemia have been reported, using high-energy devices to cut and coagulate renal parenchyma, such as the harmonic scalpel or bipolar cautery [26]. Even so, significant parenchymal bleeding can occur, requiring additional urgent methods such as sutures or clips, now in a bloody field and with a perfused kidney. The vision of the cut edge is impaired due to charring or bleeding. More recent alternatives explored experimentally have included hydrojet or KTP laser technology to selectively remove parenchyma, leaving the fibrous structures (collecting system, vessels) to be controlled before transection [27].

Closure of the collecting system

Urinary fistula/leakage can occur due to inadequate repair of collecting system entry or injudicious application of energy around the renal sinus that can result in delayed necrosis. Intraoperative identification of collecting system entry is facilitated by retrograde injection of methylene blue through an indwelling open-ended ureteric catheter. This should be routine as the surgeon can be deceived by the laparoscopic

appearance of the renal sinus. Precise suture-repair effectively achieves a watertight closure.

Prevention of primary/secondary haemorrhage

Postoperative haemostasis is intimately linked to the technique of intraoperative haemostasis. When kidney ischaemia is used the tissue is quite soft and pliable. Renal parenchyma can be re-approximated with needled absorbable braided suture over preformed bolsters of reoxidized cellulose tissue (Surgicel®, Johnson & Johnson, USA). Renal revascularization causes parenchymal turgidity and tamponading of vessels against this bolster. The thrombin/gelatin bead matrix provided by the biohaemostatic agent FloSeal® (Baxter Healthcare, USA) is a vital adjunct to promote this tamponade effect. In comparing consecutive patient series before and after using FloSeal we noted a decrease in haemorrhagic complications from 11.8% to 3.2% of patients. Interestingly, the rate of urinary leak decreased from 6% to 1.5%, and other non-haemorrhagic complications such as prolonged ileus and respiratory complications, as well as the hospital stay, were also reduced [28]. To be fully effective the thrombin-matrix sealant needs to be applied close to the tumour resection bed. With techniques that do not provide tamponade the surgeon must rely on other methods such as a potpourri combination of fibrin tissue glues, cellulose mesh, biodegradable sealants, or argon-beam coagulation. The multitude of these available haemostatic agents is testament to their potential ineffectiveness as a sole agent with any lesion that is more centrally placed than a simple peripheral wedge resection.

Results

Emerging single-institution results are provided in Table 2 [24,26,29–31]. In series where tumours were excised with no hilar control, most tumours were superficial exophytic lesions undergoing 'wedge resection'. At present there is little in the way of comparative data between LPN and OPN or laparoscopic radical nephrectomy. Series comparing cohorts from the same institution suggest that LPN would not result in any greater morbidity than laparoscopic radical nephrectomy [32]. In comparison with OPN reported series suggest that LPN was of benefit, with significantly shorter operative

TABLE 2 Results of LPN/wedge excision

Study	No. of patients	Ischaemia time, min	Excision technique	Final control	Trans/Retro peritoneal	Operating time, min	Blood loss, mL	Mean size, cm	Follow-up months,	Positive margins, n	Complications
[26]	51	0	Harmonic	Surgicel Tisseel	T 19 R 32	132	282	2	34		3 leaks 1 bleed 1 pneumothorax 1 bleed
[29]	20	0	Harmonic diathermy Tissuelink	Argon beam Tisseel Tissuelink	All T	130	120	2.1	8	1	
[24]	16	27	Cold ischaemia (ureteric irrigation)	Surgicel Flo seal + suture	All T	160	270	2.5		0	2 transfused 1 abscess 1 DVT 1 explored for bleed
[24]	12	0	Harmonic Bipolar	Bipolar	All T	180	708	1.9		0	3 transfused pancreatic laceration
[30]	100 200	28	Warm ischaemia	Surgicel Flo seal + suture	T 122 R 78	199	247	2.9		3	2 conversions 1 ureteric injury 19 transfusions 9 leaks
[31]	223	27.6	Warm ischaemia	Surgicel Flo seal + suture	T 202 R 18	186	385	2.6		7	4 conversions 2 PUJ obstruction 15 transfused 3 leak

DVT, deep vein thrombosis.

durations, less blood loss, decreased analgesic usage, earlier discharge from hospital and shorter convalescence period, although with a higher rate of complications and longer warm ischaemia times [33].

CRYOTHERAPY

The aim of energy-based tissue ablative procedures is to achieve targeted destruction of a predetermined volume of tissue that would otherwise be excised during a PN. Cryotherapy is the most studied of all the ablative techniques. Initial reports describe open and then laparoscopic insertion of a cryoprobe into a solid lesion, and subsequent freezing and thawing of the tissue. Cryoprobes are insulated instruments, super-cooled at the tip using liquid argon (-187°C) or nitrogen (-195°C). This super-cooled tip forms an 'ice-ball' around it, encompassing tumour and normal renal tissue.

This act of freezing and thawing tissue results in necrosis from a combination of direct cellular injury and indirect damage to the microvasculature [34]. Direct cellular damage can be caused by intracellular ice formation,

although this lethal event usually occurs near the probe. Most of the ice-ball has less severe freezing, which causes extracellular ice to form, increasing the extracellular osmotic concentration. Over the ensuing days indirect cell damage occurs as a consequence of the lethal damage sustained to the endothelial cells of the microvasculature, resulting in thrombosis, vascular occlusion, regional tissue ischaemia and cell death.

Indications

As long-term outcomes are not yet available, cryoablation is usually reserved for the older patient with comorbid disease who has a single, small ($\leq 3\text{--}4\text{ cm}$) exophytic tumour located away from the collecting system. Contraindications to laparoscopic cryoablation include coagulopathy, significant adhesions and centrally placed tumours.

Technique

Either the transperitoneal or the retroperitoneal laparoscopic approach can be used, depending on the location of the individual tumour. Laparoscopically, the lesion

is exposed; a needle biopsy is taken with a Trucut needle, and the cryoprobe is inserted perpendicularly through the centre of the tumour up to or just beyond the deepest margin, all under real-time ultrasonographic (US) and laparoscopic guidance. Cryoablation is performed under dual laparoscopic and US control. During percutaneous cryoablation, CT or MRI control is used, but this technique is limited to accessible (posterior or posterolateral) tumours.

Application of cryotherapy

The temperature for the direct destruction of renal cells is -19.4°C [35]. Most clinical series have erred on the side of caution and aimed to reduce tissue temperature to -40°C . Direct measurement using thermocouples placed at the tumour margin can be used to detect adequate freezing, but this is cumbersome and unreliable, therefore direct monitoring of the ice-ball has supplanted this.

Using continuous laparoscopic US monitoring, the advancing hyperechoic, semi-lunar edge of the ice-ball can be seen clearly within the tissue. Canine studies show that

TABLE 3 The results of renal cryotherapy

Variable	Study			
	[38]	[39]	[40]	[41]
Access	Lap	Open	Perc	Lap
Number of tumours	34	29	22	20
Mean size, cm	2.3	2.2	3.2	2.6
Site	9 posterior 12 lateral 13 anterior		18 posterior	6 upper 7 middle 7 lower
Mean (range) operative time, h	2.9 (1–4.5)	NA	1.5 (1–3)	5
Mean (range) blood loss, mL	67 (10–200)	200	NA	92 (50–200)
Mean follow-up, months	16	16	9	24
Contrast enhancement at 1 year	0/20		0/10	1/15
No reduction in size at 1 year	4/20	2/16	1/10	4/15
Complications	1 perirenal haematoma		4 perinephric haematoma 1 abscess	1 pancreatic injury

Lap, laparoscopic; Perc, percutaneous; NA, not available.

the ice-ball must extend 3.1 mm beyond the visible tumour margin for this margin to reach the required -20°C [36]. Allowing for this, most centres use a visible 1 cm margin to determine the adequacy of freezing and cellular destruction at the tumour periphery.

The use of a double freeze-thaw technique has been postulated to improve cell death at the margins. This is based on the experience of liver surgeons. Double freezing will produce a larger central area of liquefaction but not necessarily increase the size of the cryolesion. Allied to this, the second freeze is difficult to monitor on US. Most series rely on dual freeze and dual thaw, although the second thaw can be active, to reduce operating time [37].

Probe removal carries with it the risk of haemorrhage and fracture of the ice-ball. The chance of this is decreased if the probe is removed only when thawing has fully 'released' the probe. Twisting the probe whilst still engaged within the ice-ball is unacceptable. Bleeding can be controlled by direct application of argon-beam coagulation or bioadhesive haemostatic agents, such as Floseal. In the percutaneous approach up to 20% of patients will have minor perinephric haematomas.

The optimal frequency of imaging after treatment is uncertain and reflects the novelty nature of the technique. Our current practice consists of MRI scans at 1 days, and at 3, 6, 9 and 12 months, and annually

thereafter. No enhancement of the lesion on gadolinium-enhanced MRI is an important determinant of differentiating scar from residual tumour. Likewise, benign lesions can be expected to slowly shrink but can take months if not years to disappear. We recommend a biopsy protocol at 6 months and consider this mandatory if lesions fail to shrink at 6–12 months after treatment.

Results

Outcomes of clinical series are described in Table 3 [38–41]. Adjacent organ damage to bowel, the PUJ and pancreas have been reported occasionally, due to direct contact with the ice-ball. No systemic adverse effects such as hypertension or azotaemia have been noted.

Our clinical experience now exceeds 161 patients [42] with 56 of these being followed up for >3 years [43]. At 3 years the mean reduction in lesion size compared to the first day after surgery was 77%, while 38% of patients had no visible lesion. CT-guided biopsy as part of the follow-up protocol 6 months after treatment has, to date, been positive for tumour in two patients. Both had a successful laparoscopic radical nephrectomy secondarily, and have no evidence of disease at the last follow-up.

The introduction of percutaneous cryoablation into clinical practice now means that similar results are likely to be achieved in accessible lesions, with no need for general

anaesthesia and laparoscopy. Reported series are not yet mature, but show encouraging early results.

RFA

Similar to cryotherapy, the aim of RFA is to destroy a predetermined volume of tissue, but using high-frequency alternating current to cause a heat-based tissue damage. Current is applied through needle electrodes directly into target tissue, returning to the generator through grounding skin pads. As the electrical energy increases the tissue temperature to 60–100 $^{\circ}\text{C}$ there is denaturation of cellular proteins, melting of lipids, and instantaneous coagulative necrosis, resulting in irreversible cell damage. Like cryotherapy, a secondary zone of damage due to vascular thrombosis adds to the tissue destruction, but by contrast to the spherical ice-ball, this tends to be wedge-shaped due to segmental arterial thrombosis. The lesion heals with fibrosis and scarring [44].

Indications

There are fewer available published results than for cryotherapy, but similar indications for tumour position, size and systemic complications apply.

Technique

RFA can be done using open or laparoscopic approaches, but is generally percutaneous. The tumour is imaged on CT and CT guidance

TABLE 4 Experimental and clinical data from RFA

Study	No. of tumours	Access	Mean (range) tumour size, cm	Follow-up method	Mean (range) follow-up, months	Continual enhancement on imaging	Complications
[46]	24 (11 central)	Perc	All < 3	CT	2/12 in all	5/24	4 neuropraxia 1 perinephric haematoma
[47]	13	Perc	2.4 (1.8–3.0)	CT	5 (1–13)	1/13	1 perinephric haematoma
[48]	35 (13 central)	27 Perc 8 Open	1.7 (1–3.6)	MRI in 12 CT in 23	9 (1–35)	0/35	3 neuropraxia 1 perirenal collection
[49]	32 (3 central)	Perc	2.6 (1–5)	CT	9 (1–36)	6/32	2 perinephric haematoma. 1 puncture site metastasis
[50]	24 (15 central)	Perc	3.25 (1.0–7.0)		7 (1–35)	4/24	
[51]	56 (17 central)	Perc	2.2 (1–4)	CT	27.5 (12–48)	6/56	14 perirenal haematomas 1 liver burn 1 death from pneumonia
[42]	81 (28 central)	Perc	2.5 (0.9–4.5)	MRI	13		

Perc, percutaneous.

used to position the probe within the tumour, where the tines are deployed beyond the edge of the tumour. On completing RFA, the probe is withdrawn slowly, applying electrocautery to the tract to prevent haemorrhage. Like cryoablation, it is restricted to small lesions of maximum diameter 3–4 cm. The aim of treatment is ensure destruction of the tumour and a rim of surrounding normal parenchyma. In larger lesions, overlapping radiolesions need to be created to ensure complete tumour treatment. Although the specifics of energy administration vary among studies, the key issues affecting real-time treatment efficacy are as follows.

Real-time imaging: The ability of US to visualize a developing radiolesion is hampered by RF interference and microbubble formation at the periphery of the induced lesion of destruction [44]. CT and MRI might hold promise in identifying the edge of the necrotic lesion, as bubbling causes less interference than with US. Presently, real-time radiological visualization is unreliable as a treatment endpoint.

Energy input: With no lesion visible to highlight the edge of tissue destruction, the energy imparted to the tissue must be monitored to provide a reasonable estimate of the depth of penetration of sufficient heat to cause tumour necrosis. The two commonly used systems are:

(i) Temperature monitoring, based on the temperature at the tip of the probe. Sufficient

energy is delivered to raise the temperature monitored at the tip of the electrode to 60–100 °C. This temperature is maintained for a predetermined period. The drawback to this system is that the time the temperature is maintained at this level is calculated from previous experimental data rather than any real-time feedback from active temperature monitoring at the periphery of the lesion. If a lesion is near a vascular structure, e.g. centrally, a 'heat sink phenomenon' occurs, with the blood flow draining heat from the edge of the tumour.

(ii) Impedance monitoring. As the temperature increases to >100 °C, tissue charring and rapid rises in impedance occur, reducing energy transfer through this tissue. Impedance-based monitoring systems apply energy until a predetermined level of impedance is reached, implying that sufficient cellular destruction must have occurred. The drawbacks of this system are that different tissues produce different impedance levels, and temperature might not reach a high enough level to cause tumour necrosis.

Tumour size: Rapid heating causes tissue desiccation, which increases impedance, thereby limiting the size of the radiolesion. Various techniques have been used to enhance the size and uniformity of RF lesions. These include:

(i) Multiple passes into the lesion and/or withdrawal of the probe with repeated energy cycles. This is the most commonly applied technique, but due to charring and

impedance, even closely applied energy cycles might not penetrate previously targeted areas.

(ii) Cluster needles in which a series of tines are deployed from the tip of the probe and RFA is applied to each tip simultaneously. As these act like multiple mini-probes, larger and more uniform lesions are created.

(iii) Internally cooled tips that increase the zone of destruction by selectively limiting the heat rise closest to the electrode.

(iv) Animal studies include:

- Saline-enhanced RFA (wet RFA), that involves infusion of saline directly into tissue parenchyma before or during treatment. This facilitates the conduction of electricity and heat away from the tip, and expands the thermal zone and destroyed lesion. However, the subsequent size and shape of the lesion is not uniform.
- Transient arterial clamping [45].

Results

The results of the various series are presented in Table 4 [42,46–51]; although this is a heterogeneous group, several important concepts can be highlighted.

(i) The destruction of the lesion becomes increasingly unreliable at its periphery, which implies that the surgeon has to consider multiple passes in smaller lesions to be confident of success.

(ii) Most series rely on imaging to determine tumour destruction for tumours that are

renowned for being slow-growing in the first place. Histological evidence, obtained by either nephrectomy or PN after RFA, suggests that not only is there a significant chance that viable tumour cells will remain, but that they can do so in the absence of enhancement on cross-sectional imaging.

(iii) There appears to be a higher rise in serum creatinine level than would be expected from partial or cryotherapy.

HIFU

This technique is still highly experimental and investigations continue into several technical factors, but there is little reported about its use in the clinical setting. Similarly to extracorporeal shockwave lithotripsy, ultrasound waves created by a piezolith crystal dish converge on the intracorporeal focal point, where several thermal (temperature rise of up to 90 °C) and non-thermal (cavitation, cellular oscillation) effects cause tissue damage, resulting in coagulation necrosis [52].

Its attraction lies in the perception that it is the ultimate in minimally invasive therapies for, as in extracorporeal shockwave lithotripsy, the only physical contact between patient and instrument is the coupling between the patient's skin and a membrane containing degassed water. The application of this energy source would appear to induce no worsening of renal function in phase 1 studies, but clinical experience with this technique is limited [53], and because it is experimental, no data attesting to the oncological efficacy are likely to be available for some time.

CONCLUSIONS

OPN has matured to the point where 10-year survival data comparable to those from radical nephrectomy series are achievable. Minimally invasive approaches must equal such excellent oncological results. Techniques seem to be developing into three distinct categories; excision, probe ablation and noninvasive ablation. Of these, the most experimental is certainly the latter, but with refinements in HIFU energy delivery, patient and tumour selection, and imaging, it is conceivable that this might ultimately find a suitable role, albeit that this is unlikely in the near future. Cryotherapy and RFA are both within the bounds of the capability of a

competent laparoscopist, certainly with less difficulty and lower morbidity than LPN. Cryotherapy seems to have the advantage in reliability of tissue destruction and is a fairly well established technique. With encouraging 3-year follow-up data from the Cleveland Clinic supporting its efficacy in selected patients (and 5-year data available in the near future), it is the closest to the threshold of clinical acceptance. The availability of percutaneous approaches means that these procedures can be performed in patients unsuitable for general anaesthesia, although the percutaneous approach is usually only suitable for posterior and posteromedial tumours.

Whilst cryotherapy remains just over the horizon, then undoubtedly for centres with sufficient experience, LPN has the most immediate clinical application and relevance. Although currently, in expert hands, most small renal tumours can be excised laparoscopically, a few contraindications exist, e.g. the occasional central and completely intrarenal tumour is best removed by open surgery. Although many alternative haemostatic devices are being used to 'shoehorn' LPN into wider acceptability, these alter the established tenets of OPN and the technique must be examined rigorously to avoid suboptimal results. Laparoscopic surgery should aim to mirror what has been established and practised safely and effectively in open surgery. Emulating the established techniques for OPN has allowed LPN to emerge as a viable alternative with excellent oncological and functional results.

CONFLICT OF INTEREST

None declared.

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Abbreviations: (MI)NSS, (minimally invasive) nephron-sparing surgery; (O)(L)PN, (open) (laparoscopic) partial nephrectomy; RFA, radiofrequency ablation; US, ultrasonographic.