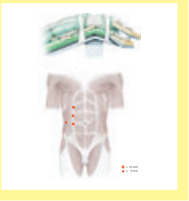
Surgery Illustrated



Laparoscopic partial nephrectomy

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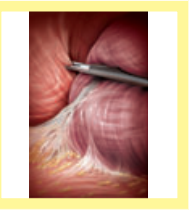
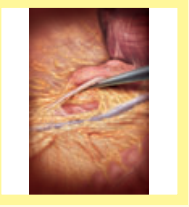
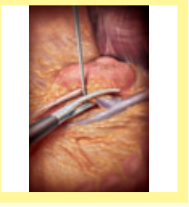
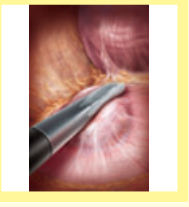
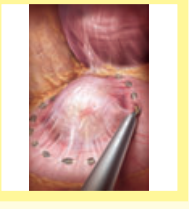










INTRODUCTION

In properly selected patients with a small renal tumour, open partial nephrectomy (OPN) and traditional radical nephrectomy yield comparable intermediate and long-term oncological outcomes [1–5]. Concomitantly, the incidental detection of small (≤4 cm) renal tumours has increased, thus expanding the indications for nephron-sparing techniques in contemporary patients with renal cancer. Finally, advances in laparoscopic skills and technology have increased exponentially. This has led to enhanced confidence and experience with renal hilar vascular control, renal hypothermia (if required), 'cold-cut' tumour excision, calyceal suture repair, and precise, time-sensitive haemostatic parenchymal sutured reconstruction. As a result of such factors, laparoscopic PN (LPN) has emerged as an attractive minimally invasive alternative to OPN. LPN, by the transperitoneal or retroperitoneal approach depending upon the tumour, duplicates the established principles of OPN [6]. Emerging reports documenting reproducible technical, peri-operative, pathological, functional and intermediate-term oncological outcomes comparable with OPN are likely to lead to more widespread application of LPN.

Indications for LPN, initially limited to the small, solitary, peripheral, superficial, exophytic renal tumour, have now been carefully expanded to include patients with tumour infiltrating the parenchyma up to the collecting system or the renal sinus, completely intrarenal tumours, tumour abutting the renal hilum, tumour in a solitary kidney, large tumour requiring heminephrectomy, or a renal mass in the presence of concomitant renovascular disease. Relative contraindications to LPN include morbid obesity, and the presence of two or more tumours. Clear contraindications for LPN include previous OPN, concomitant vein thrombosis, and a mid-pole completely intrarenal tumour. The haemorrhagic risk is increased in patients with haemorrhagic diathesis, platelet dysfunction due to azotaemia, or anticoagulant therapy. Such patients should be approached cautiously, with adequate medical preparation before LPN. The risk of intimal injury during renal artery clamping is increased in patients with atherosclerotic renovascular disease or those who have had percutaneous renal artery stenting. Finally, adequate laparoscopic experience and expertise are implicit before embarking on LPN. Here we present the transperitoneal technique (our preferred approach) of LPN. Technical differences with the retroperitoneal approach are mentioned.

PATIENT PREPARATION

Informed patient consent is obtained. Kidney function tests and clotting profile are evaluated before LPN, with routine blood tests. Three-dimensional CT with 3 mm sections of the kidney is obtained to precisely delineate tumour location, its proximity to the pelvicalyceal system and renal sinus, and identify the number and location of renal hilar vessels, interrelationships amongst vessels, and possible vascular anomalies.

The patient is instructed to discontinue any anticoagulant medications at an appropriate

time before surgery. Aspirin products are stopped 10 days before while warfarin is discontinued at least 5–7 days before surgery. On occasion, in patients with a prosthetic heart valve, a haematology consultation is necessary to coordinate safe discontinuation of anticoagulation. Bowel preparation comprises of clear fluids and two bottles of magnesium citrate in the afternoon before surgery. After midnight the patient discontinues oral intake. The patient is admitted to the hospital on the morning of the operation. A parenteral broad-spectrum antibiotic is given on-call to the operating room.

INSTRUMENTATION

LPN is an advanced laparoscopic procedure; the entire operating team should be familiar with all equipment and the sequential operative steps. We use a basic laparoscopic set including a Veress needle, blunt-tip 5-mm and 10/12 mm ports, atraumatic bowel graspers, J-hook electrocautery, disposable laparoscopic scissors, Allis clamp, Maryland grasper, disposable 10-mm, titanium clip applier, Hem-o-lok™ clips (10 mm) and applicator (Weck Closure System, NC, USA), 10-mm right-angle clamp, bulldog clamps, and the Carter-Thompson port-site closure device. A suction system (Stryker Endoscopy, San Jose, CA, USA) allows robust suction/irrigation and its smooth, blunt, reusable tip facilitates gentle, atraumatic dissection in the area of the renal hilum. Straight 5-mm needle drivers (Ethicon, NJ, USA; catalogue #E705R) are easy to handle and allow strong, reliable grasping. A Satinsky vascular clamp (Medtronic, Minneapolis, MN, USA; catalogue #CEV435-2) allows efficient hilar clamping. A CT-1 needle with 2/0 polyglactin and a CTX needle with 0-polyglactin are used to for the sutured renal reconstruction. We routinely layer the PN bed with the haemostatic agent Floseal (Baxter Healthcare, Deerfield, IL, USA), delivered by a reusable metal laparoscopic applicator. The round Autosuture pre-peritoneal dilatation balloon (Tyco Healthcare, Norwalk, CN, USA; OMS-PDB1000) allows the creation of an optimal working space for retroperitoneal LPN.

PATIENT POSITIONING

After endotracheal general anaesthesia, an orogastric tube is placed to deflate the stomach. With the patient in the lithotomy position, a 5 F open-ended ureteric catheter over a 'glidewire' is inserted cystoscopically up to the ipsilateral renal pelvis. Using i.v. extension tubing, a 60-mL syringe filled with dilute indigo carmine dye (one ampoule of indigo carmine diluted in 500 mL saline) is connected to the ureteric catheter, secured to the Foley catheter with silk ties. Retrograde injection, using the syringe and the tubing, which are maintained sterile on the operative field, allows the detection of collecting-system entry during tumour excision.

The decision on the laparoscopic approach, transperitoneal or retroperitoneal, is made by evaluating the precise tumour location on cross-sectional CT sections (3 mm). We approach transperitoneally any tumour located anterior to the straight line drawn medial-to-lateral from the renal hilum to the most convex point on the lateral surface of the kidney; any tumour posterior to this line is approached retroperitoneoscopically. A transperitoneal approach is used by default if the drawn line transgresses the tumour. We generally prefer the transperitoneal approach because of its larger working space and superior suturing angles for better and reliable reconstruction of the PN defect.

Figure 1a

For transperitoneal LPN, the patient is placed in a 45–60° lateral position on the operating table. To prevent postoperative neuromuscular strain, the head, neck, arms, axilla, hips, legs and ankles are each ergonomically placed in a neutral position and generously padded with foam padding. Care is taken not to obstruct any i.v. line. Pneumatic compression stockings are applied to both legs. The patient is secured to the operating table at the level of chest and iliac crest, using 15 cm silk tape, thus permitting safe table rotation during LPN.

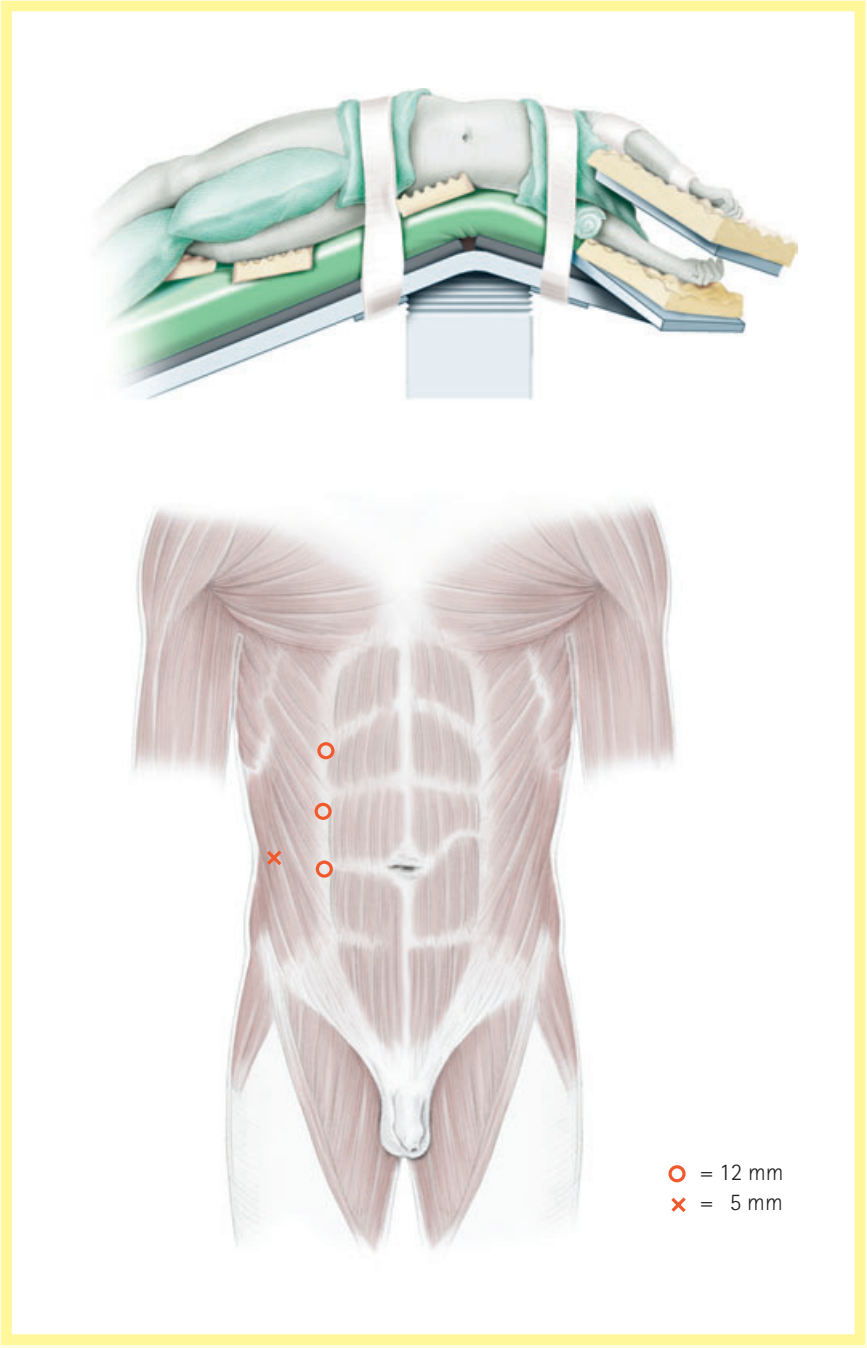
INTRAOPERATIVE FLUID MANAGEMENT

Adequate intraoperative hydration and diuresis are essential; i.v. fluids are administered according to the patient's baseline cardiopulmonary status and renal function. Mannitol (12.5 g) and furosemide (10–20 mg) are given 30–45 min before hilar clamping and repeated 2–3 min before unclamping the renal hilum, to promote diuresis, and to minimize the sequelae of renal revascularization injury, cell swelling and free radical release.

PORT PLACEMENT

Figure 1b

To obtain pneumoperitoneum, a Veress needle is placed into the ipsilateral lower abdominal quadrant along the midclavicular line. CO_2 pneumoperitoneum (15 mmHg) is achieved and four secondary ports are placed: a 12-mm laparoscopic port (primary port) placed lateral to the rectus muscle at the level of the umbilicus; a subcostal port lateral to the rectus muscle at the 12th rib costochondral margin (on the right side; this subcostal 10/12 mm port allows passage of suture needles for the right-handed surgeon; on the left side, this subcostal port is typically a 5-mm port); a 10/12 mm port for the laparoscopic camera is placed 3 cm inferior and medial to the subcostal port; a 5-mm port is inserted at the mid-axillary line near the tip of the 11th rib, and used to place lateral counter-traction during renal hilar dissection, and to grasp renorraphy sutures during renal parenchymal repair; and finally, a 10/12-mm port is placed in the suprapubic area at the lateral edge of the rectus muscle for insertion of the Satinsky vascular clamp. This standard configuration can be varied according to the individual patient anatomy and tumour location.



HILAR DISSECTION

Renal hilar dissection first, followed subsequently by mobilization of kidney and tumour identification, constitutes our essential operative strategy.

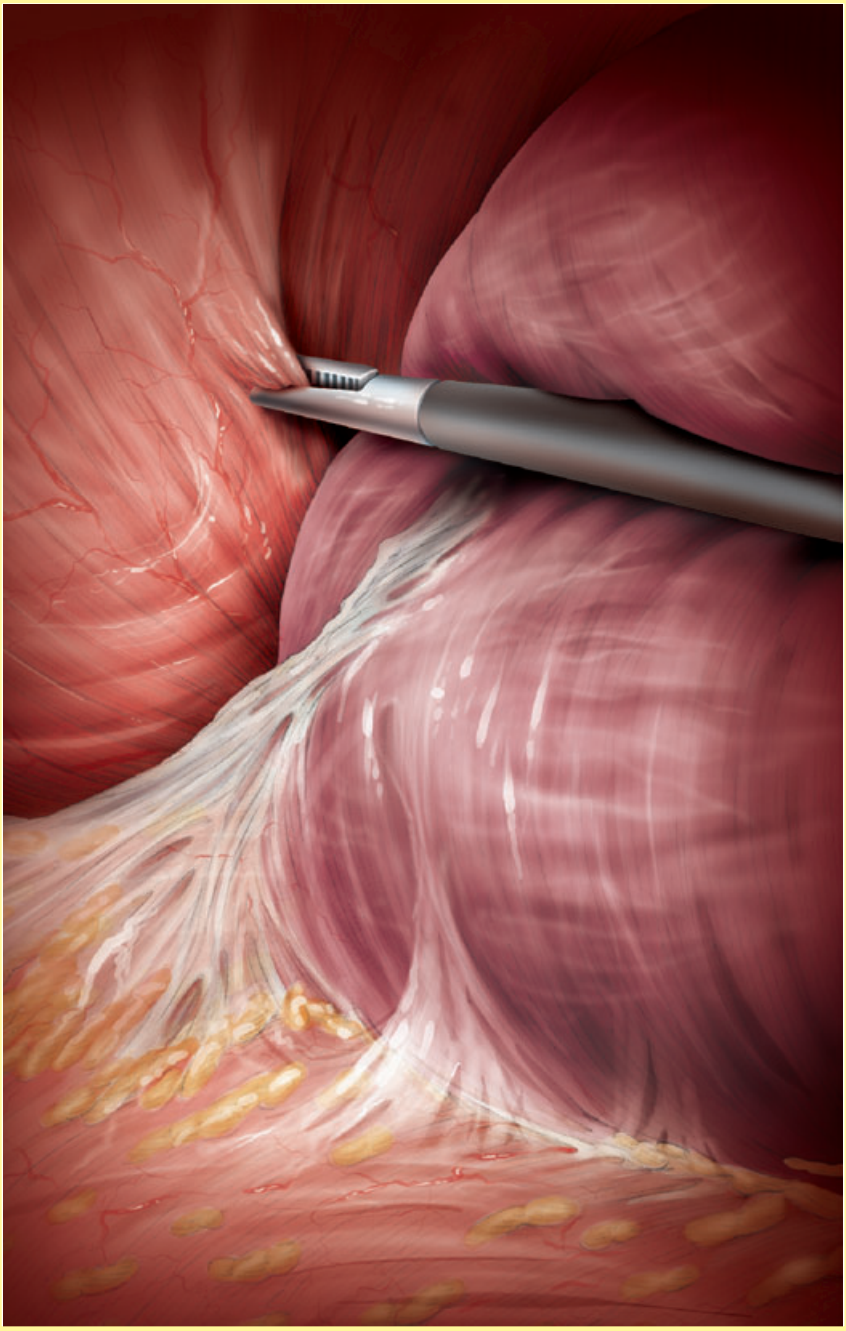
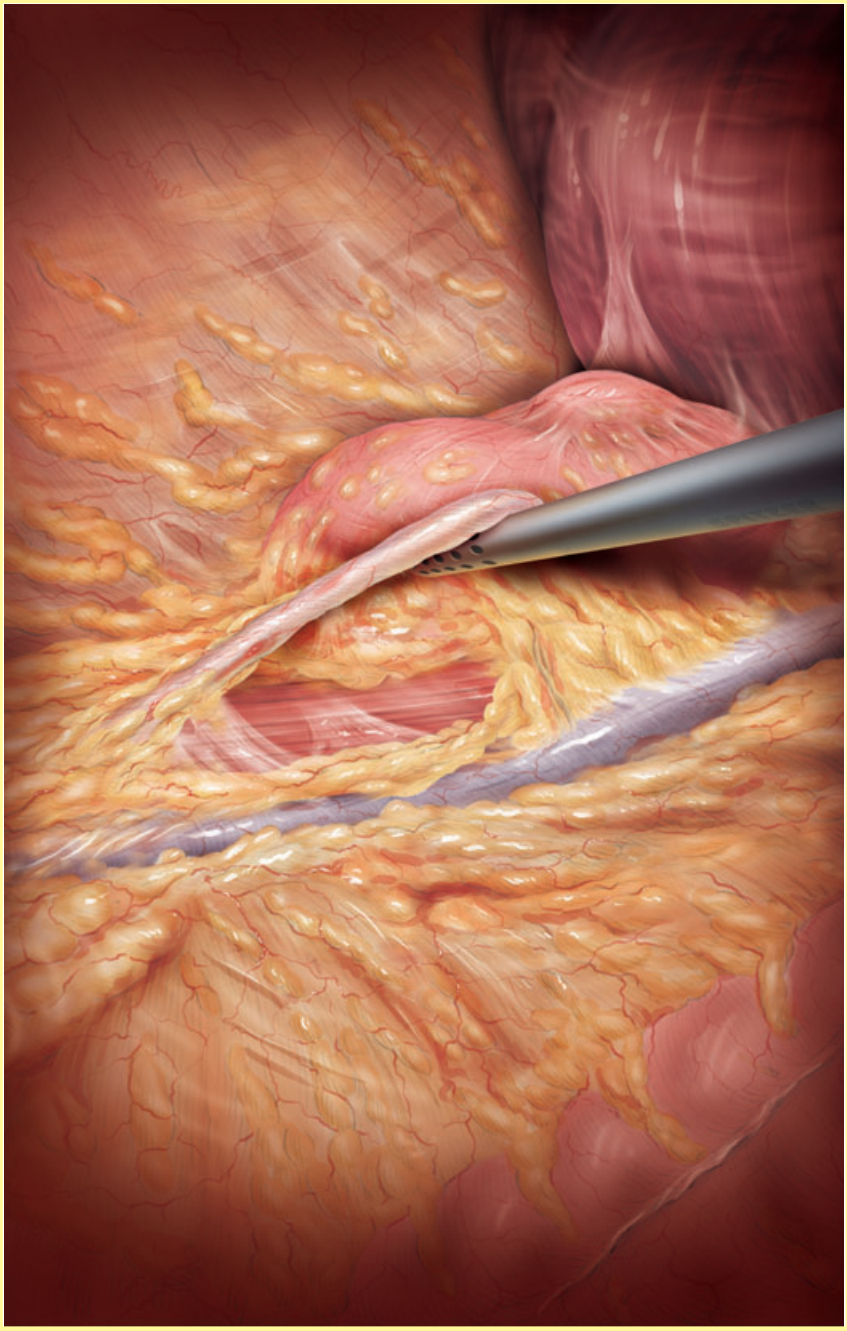


Figure 2

During right LPN, the liver is retracted anteriorly and cephalad to expose the renal upper pole. During left LPN, the spleen, splenic flexure and pancreas are reflected medially. On either side, the ipsilateral colon is mobilized to expose the renal hilum. On the right side, gentle mobilization of the duodenum may be needed.

Figure 3

The ureter and gonadal vein packet are dissected *en bloc* and lifted antero-laterally off the psoas muscle towards the renal hilum. Extended dissection is used to precisely locate the renal vein and to visualize its entire anterior surface. We do not separately skeletonize the renal vein and artery during LPN. We think that individual vessel skeletonization is unnecessary, and might even be counter-productive for the following reasons: (a) is not mandatory for achieving adequate clamping; (b) it might result in renal artery vasospasm; (c) it increases the risks of iatrogenic vascular injury with serious sequelae; (d) some hilar fat might cushion the renal vessels, minimizing crush injury to the endothelium by the clamp, especially in cases of atherosclerotic renal arteries; and (e) it requires ≈30 min of precious operating time, detracting the surgeon from the primary goal of the procedure. The medial aspect of the upper pole kidney is mobilized away from the adrenal gland, and anteriorly off the psoas muscle. The *en bloc* renal hilum, including its anterior, posterior, inferior and superior aspects, and some intact hilar fat, are prepared. Abnormally thick fatty tissue in the hilar area is dissected to avoid incomplete Satinsky occlusion.



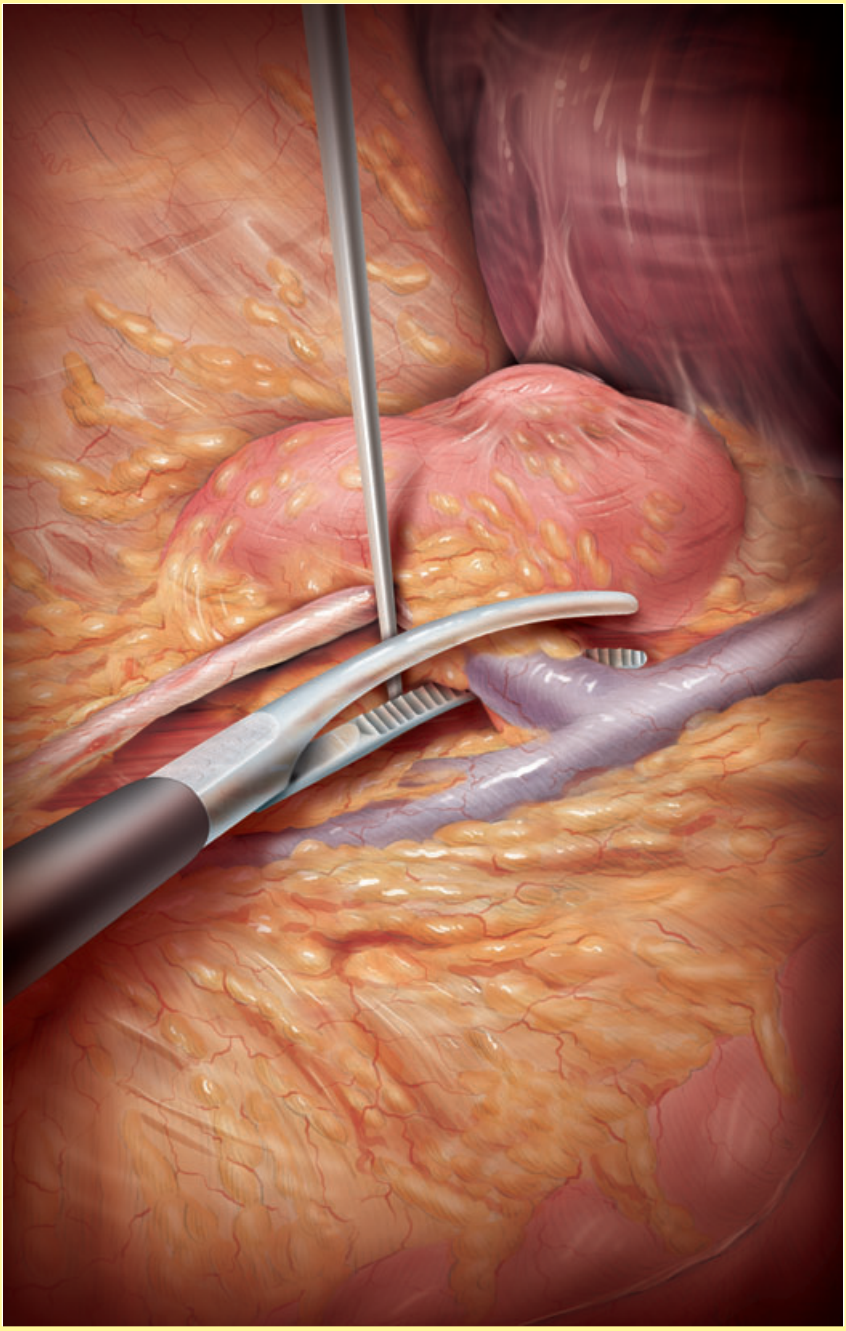


Figure 4

Through the dedicated suprapubic port in the lower abdomen, a Satinsky vascular clamp can now be inserted parallel to the aorta and inferior vena cava and test-deployed to confirm complete clamping of the *en bloc* renal hilum with safety and confidence. Any secondary renal arteries or veins must be identified carefully, and clamped individually if necessary, with bulldog clamps.

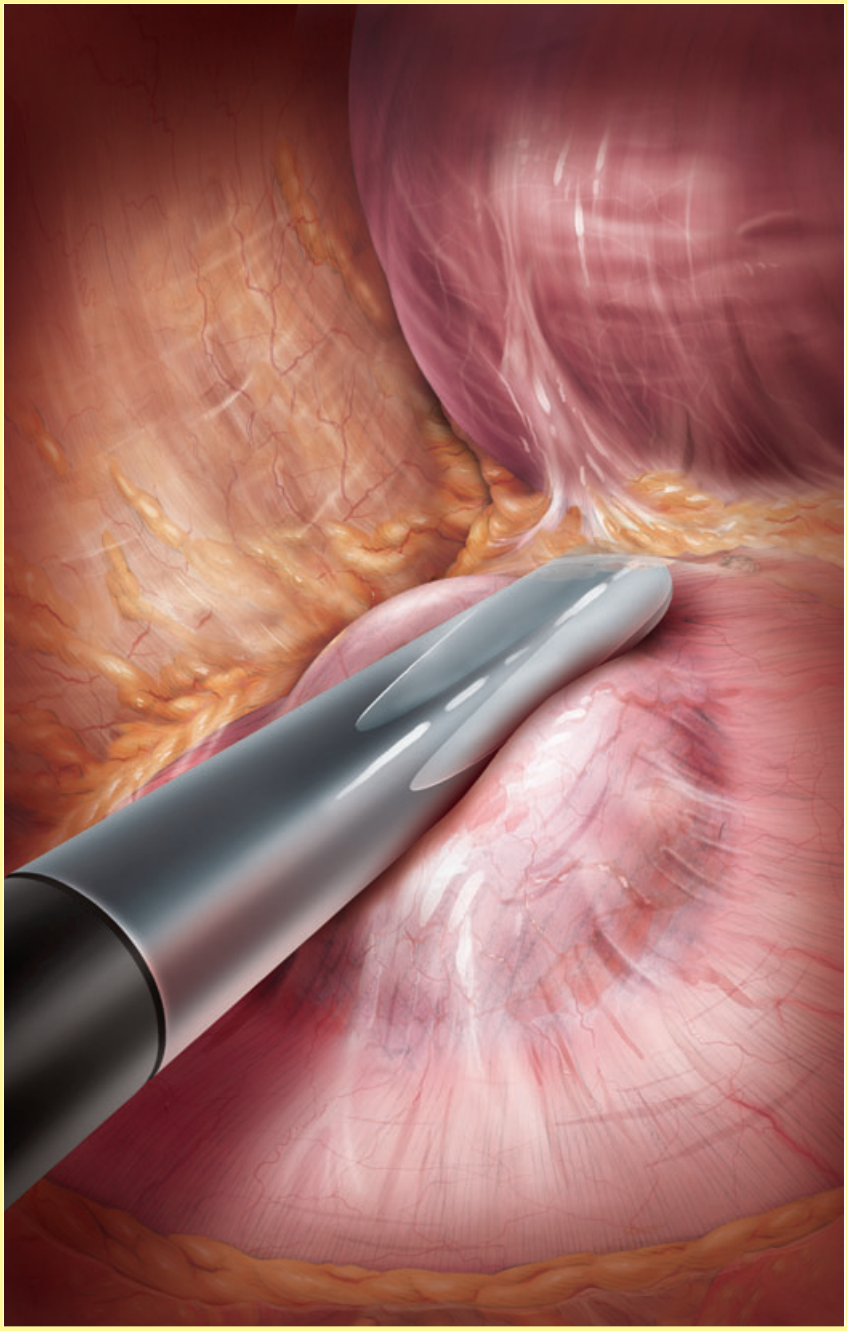
MOBILIZATION OF THE KIDNEY

Gerota's fascia is entered, and the kidney defatted and mobilized enough to expose the tumour and surrounding normal renal parenchyma. Fat removal from most of the renal surface (a) increases kidney mobility, (b) enhances visualization of any secondary satellite tumours, (c) allows multidirectional intraoperative ultrasonography (US), and (d) increases versatility for tumour resection and suturing angles. Adequate staging of potential T3a tumours and safe tumour mobilization during resection are achieved by maintaining intact the perirenal fat overlying the tumour.

INTRAOPERATIVE US

Figure 5

Using a steerable, flexible, colour-Doppler ultrasound probe introduced through a 10/12-mm port and positioned in direct contact with the surface of the kidney, information is obtained on tumour size, depth of intraparenchymal extension, distance of tumour from the pelvicalyceal system, the presence of any satellite tumour possibly missed on preoperative CT, and visualization of large intrarenal vessels.



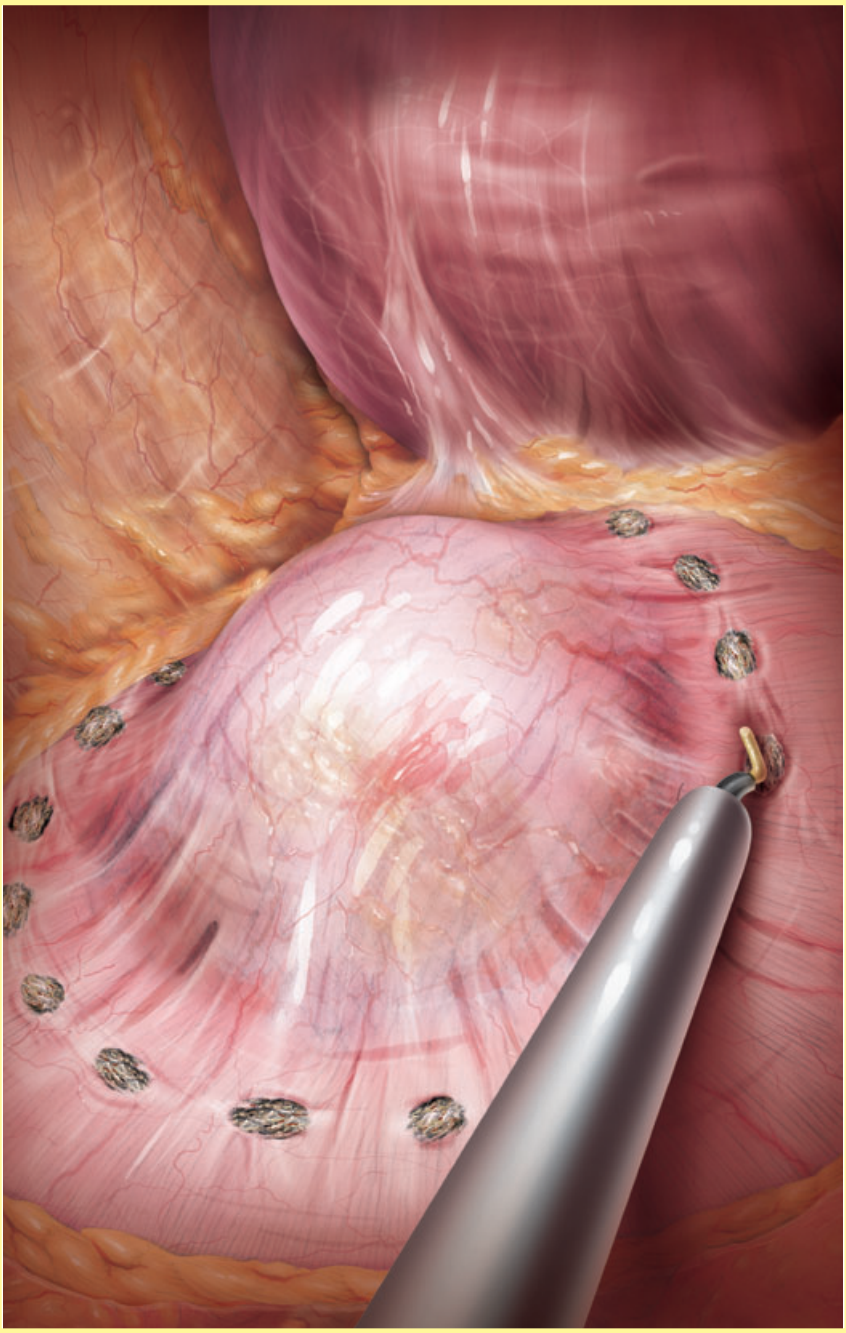


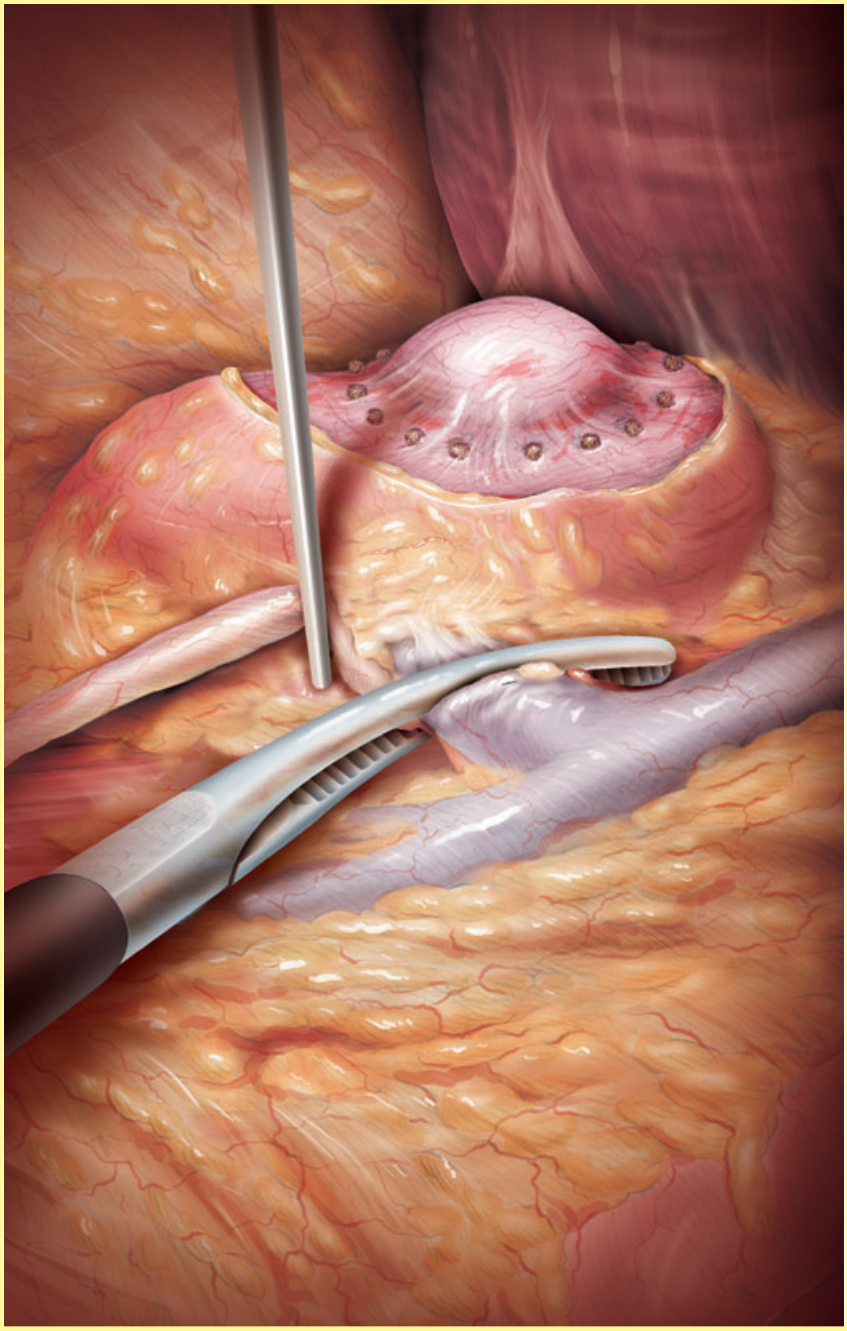
Figure 6

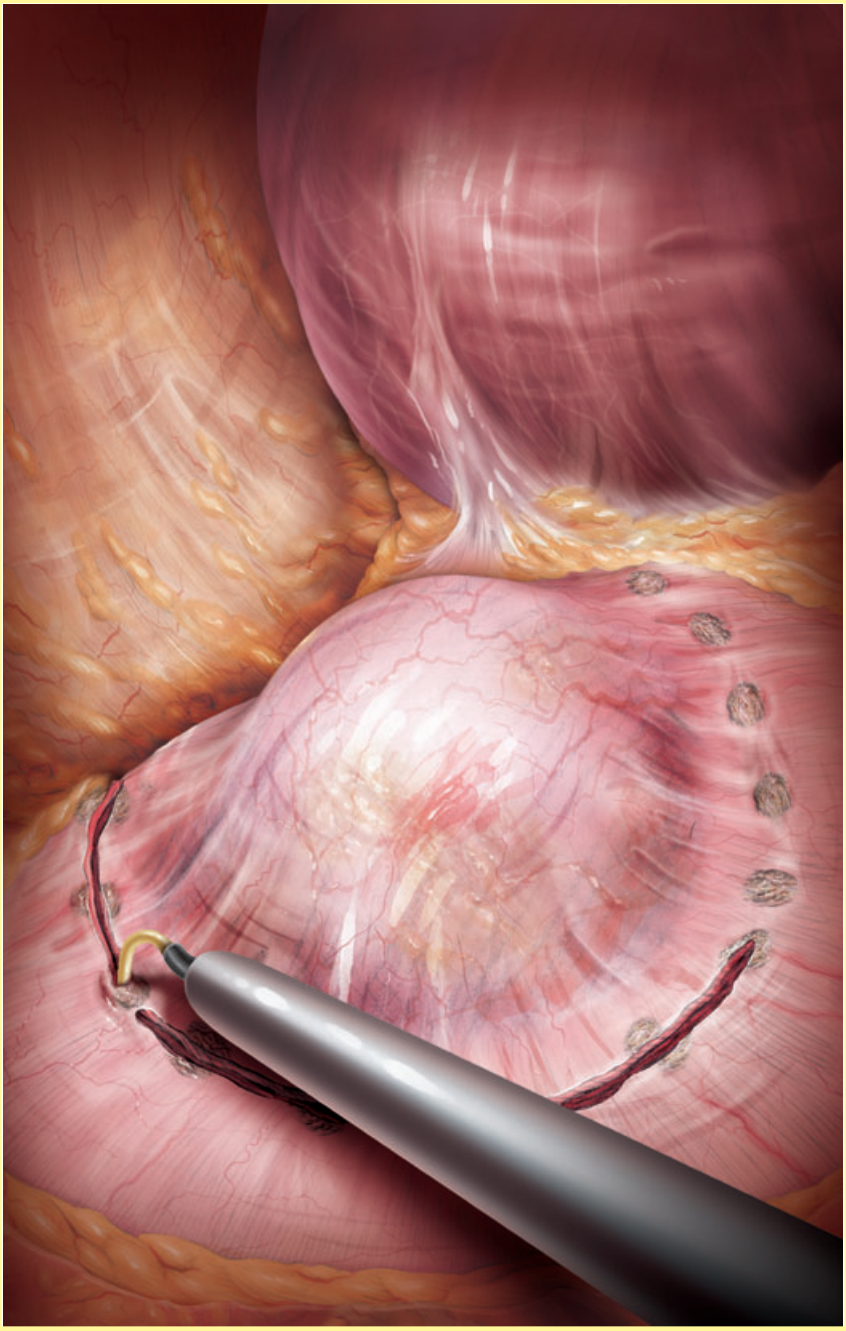
Using the tip of the monopolar J-hook electrocautery, the proposed line of excision is circumferentially scored on the renal capsule around the tumour under real-time US guidance.

HILAR CLAMPING

Figure 7

En bloc hilar clamping provides a near bloodless surgical field, which is necessary to achieve technically precise tumour excision, and collecting system and parenchymal repair. The tip of the suction cannula allows atraumatic, blunt and gentle dissection of the posterior aspect of the renal hilum, carefully avoiding any lumbar vessels in this area. A Satinsky clamp, inserted through the suprapubic port is placed across the hilum, medial to the ureter and renal pelvis to prevent urothelial crush injury. The duration of warm ischaemia is monitored using a stopwatch.





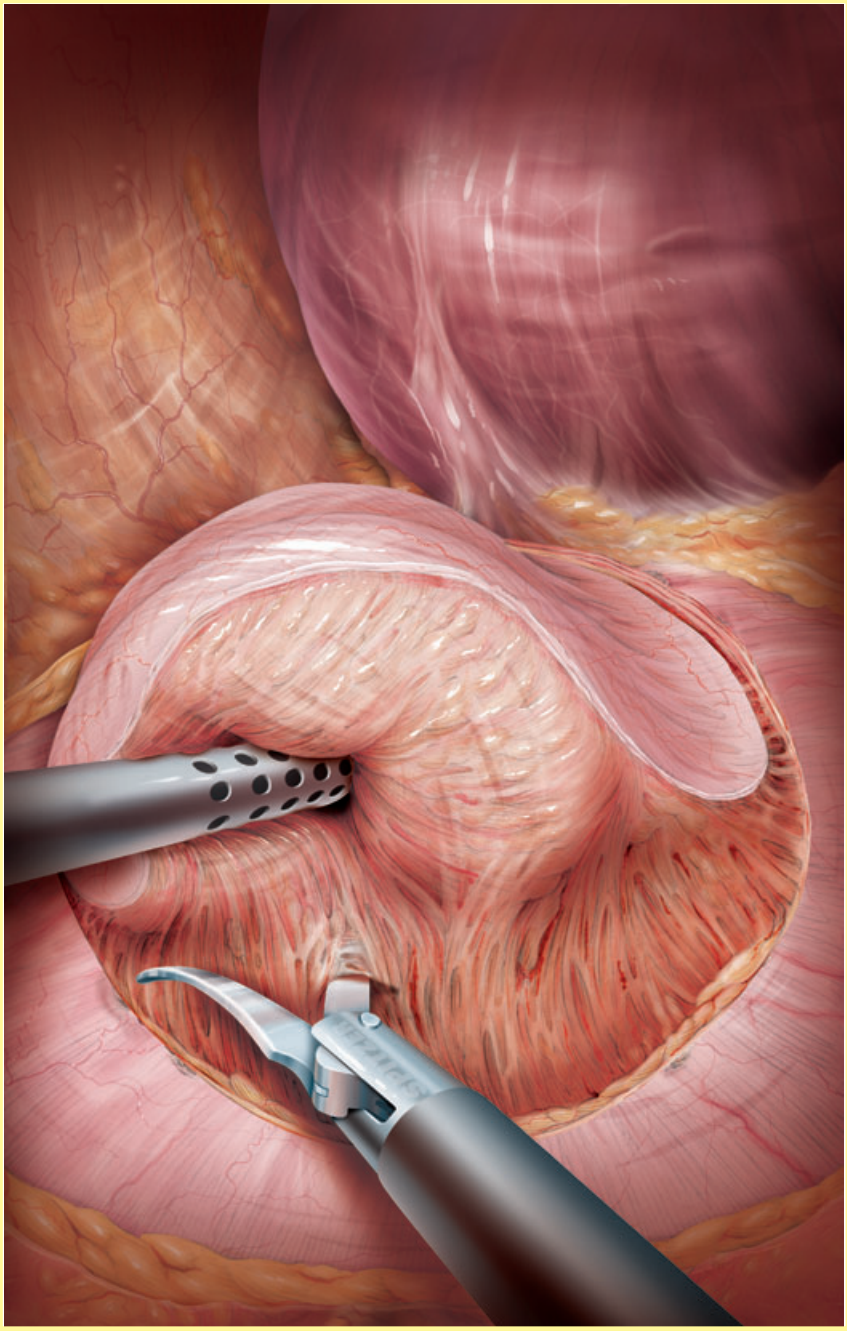
TUMOUR RESECTION

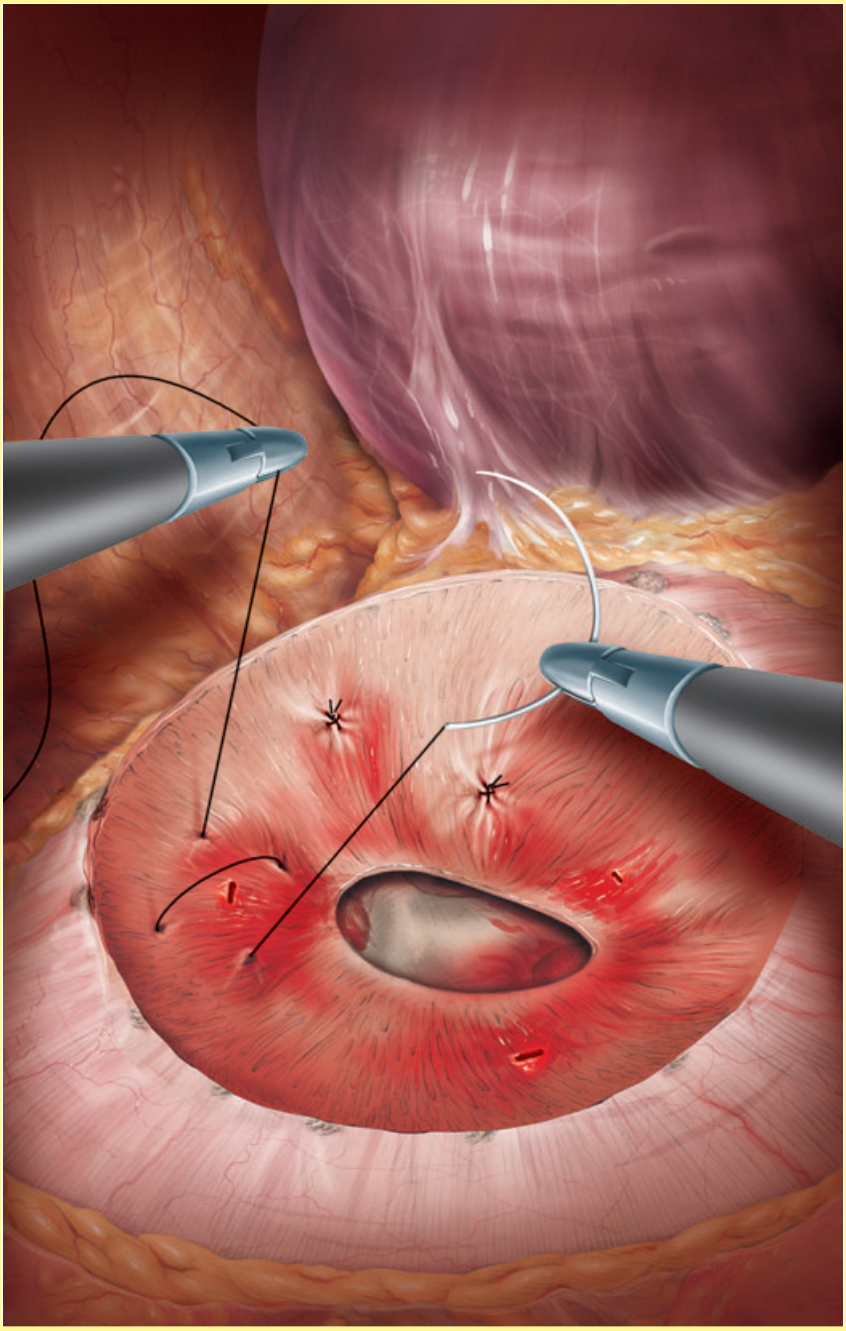
Figure 8

Once the renal hilum is clamped, the J-hook electrocautery is used to circumferentially incise the renal capsule.

Figure 9

The parenchyma is resected using the 'cold' reusable endoscissors. Compared with the disposable endoshears, the jaws of the reusable scissors are larger, thereby facilitating tumour excision. The preserved perirenal fat attached to the tumour is grasped and placed on counter-traction to elevate the tumour away from the tumour bed. A clear operative field is achieved by active, intermittent suction of blood from the PN bed. To guide the depth of tumour resection, the surgeon creates a three-dimensional mental map of the proposed excision, by collating information from preoperative CT, intraoperative US, and the direct magnified laparoscopic visualization. A parenchymal margin of ≈0.5 cm around the tumour is targeted. Given the magnification afforded by the laparoscope, such a margin can visually seem to the naive laparoscopist as if an excessive amount of kidney is being excised. 'Cold' endoshears without electrocautery are used to sharply divide, as necessary, an adjacent calyx if entry into the calyceal system is required to achieve a negative margin.

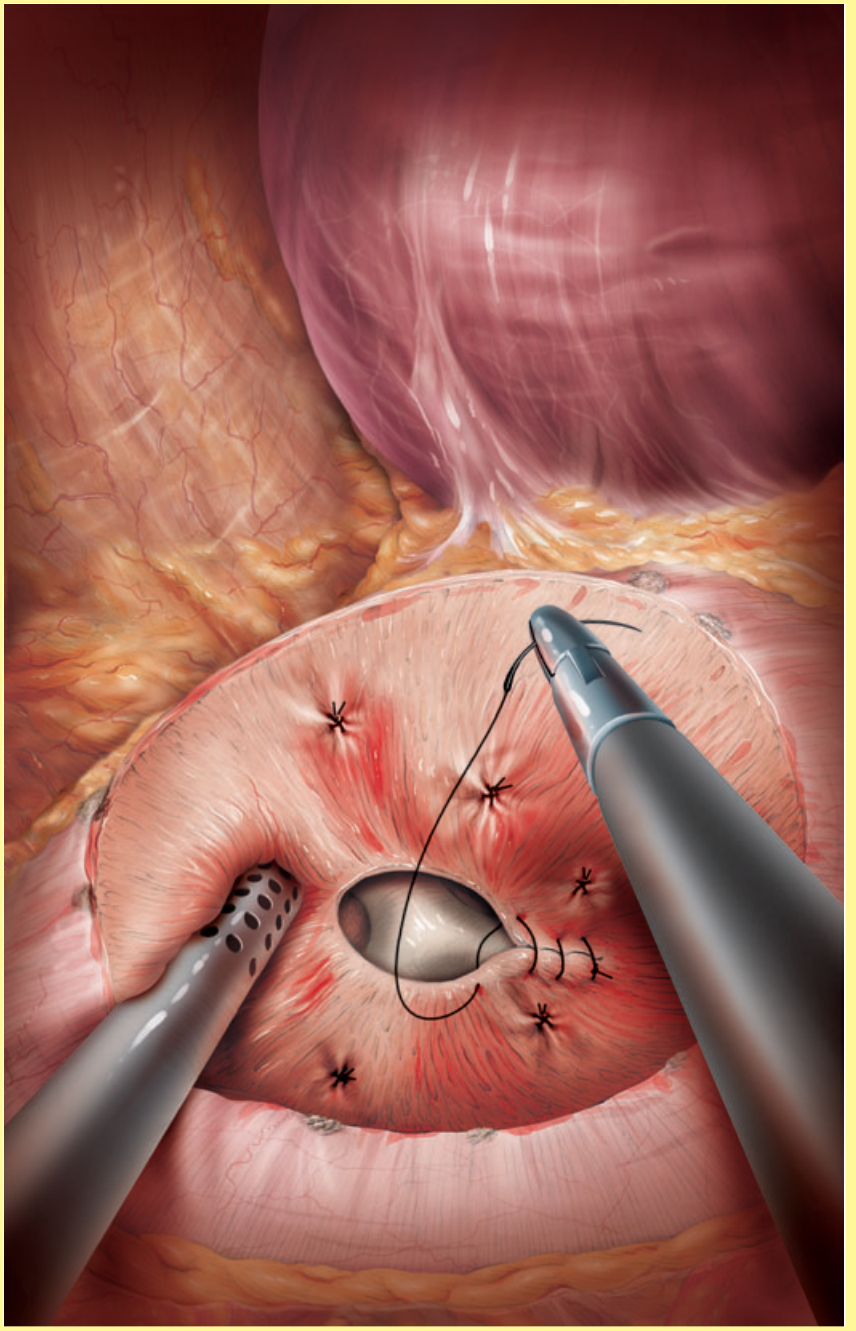


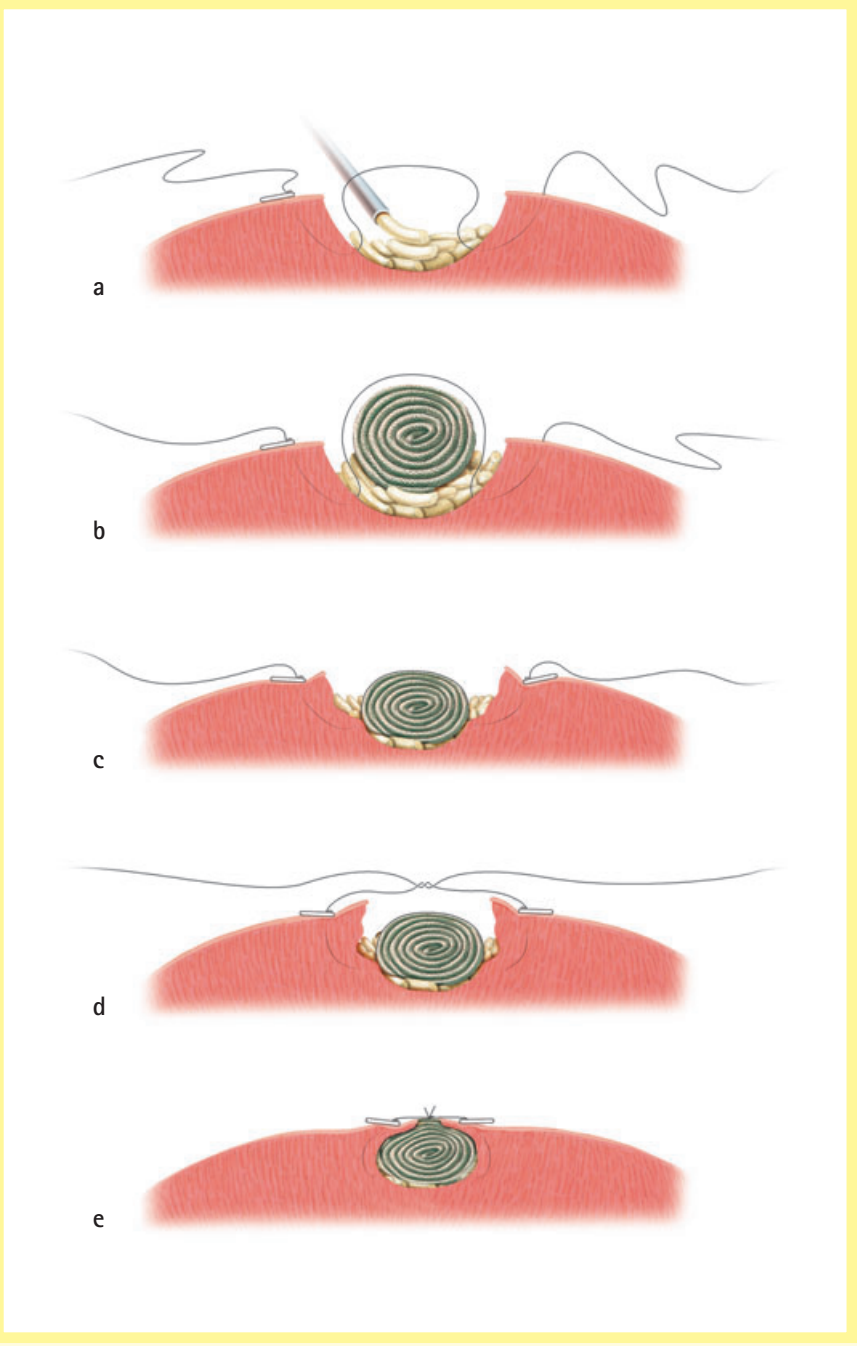


PELVICALYCEAL REPAIR AND PARENCHYMAL HAEMOSTASIS

Figures 10 and 11

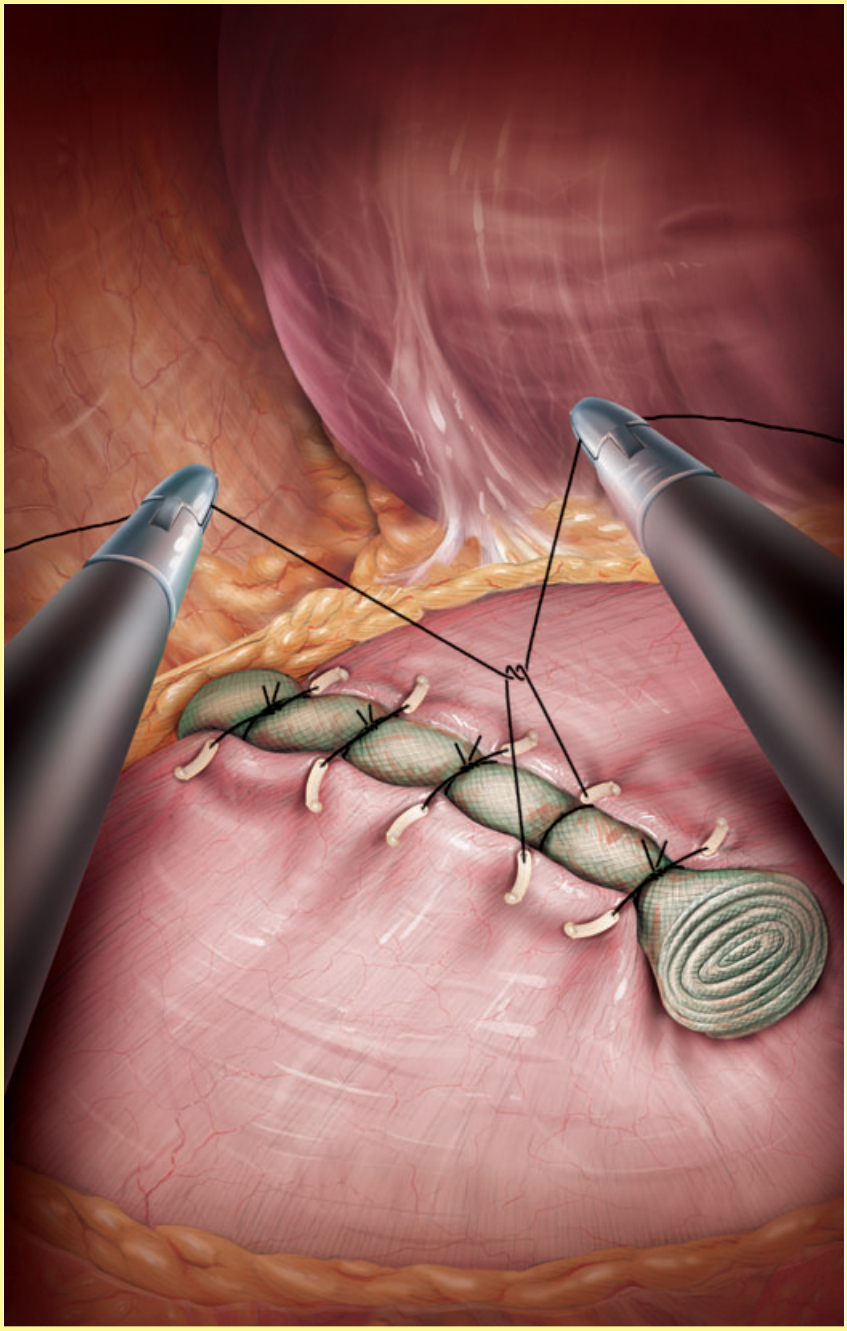
Suturing the bed of the PN defect with a running 2/0 polyglactin on a CT-1 needle aims to achieve: (a) precise water-tight repair of any pelvicalyceal system entry; and (b) over-suturing of all sizeable transected intrarenal blood vessels. If necessary, individual figure-of-eight sutures can be placed at the precise location of a large transected blood vessel in the parenchyma. Retrograde injection of dilute indigo carmine through the previously placed ureteric catheter precisely identifies any calyceal entry, and helps to confirm a watertight pelvicalyceal suture repair.





Figures 12 and 13

Parenchymal renorraphy is performed with #1 polyglactin on a CTX needle (suture length 30 cm) over a pre-prepared oxidized cellulose bolster (Surgicel, Johnson & Johnson, New Brunswick, NJ, USA), which is positioned underneath the individual suture loops. A Hem-o-lok clip placed previously 10 cm from the tail end of the suture, serves as a pledget. The meticulous placing of renal parenchymal sutures along a planned angle and depth of needle passage is important to prevent multiple needle passages. A biological haemostatic agent, gelatine-matrix thrombin sealant (Floseal) is layered directly on the PN bed underneath the Surgicel bolster. A 5-mm metal applicator is used for injection (Fig. 12). After suture tightening to firmly compress the bolster onto the PN bed, another Hem-o-lok clip is placed on the exiting suture flush with the parenchyma to maintain consistent pressure (Fig. 12). The two suture tails are tightly tied together with a surgeon's knot (Figs 12d,e). Reconstructing the entire parenchymal defect typically requires 3–5 renorraphy sutures. Bleeding from the edges of a substantive PN defect can occur if inadequate parenchymal compression is attempted by merely placing a clip as a pledget on either end of the suture. We think that effective coaptation of the edges of the parenchymal defect requires tying the suture tails across the bolster.



HILAR UNCLAMPING

The i.v. administration of 12.5 g mannitol and 10–20 mg furosemide is repeated 2–3 min before hilar unclamping. The Satinsky clamp is unclamped and maintained in place to assess the adequacy of haemostasis from the PN bed. Once haemostasis is confirmed, the clamp is carefully removed under direct vision. The warm ischaemia time is noted. Haemostasis is re-checked laparoscopically after desufflating the abdomen for 5–10 min.

LAPAROSCOPIC EXIT

Slight extension of one of the port-site incisions allows intact extraction of the specimen previously entrapped in an Endocatch bag (USSC, Norwalk, CT, USA). After transperitoneal LPN we place a Jackson-Pratt drain. After retroperitoneoscopic LPN, we leave a Penrose drain with no suction. The Carter-Thompson device is used for the fascial closure of the 10/12-mm port sites. The surgeons must inspect the specimen with the pathologist, to confirm negative margins before terminating the procedure.

RENAL HYPOTHERMIA

Although transient renal hilar clamping provides a bloodless operative field, it results in warm ischaemia. As renal metabolic activity is almost completely suspended at 5–20 °C, hypothermia affords cellular protection and minimizes renal injury after ischaemia. As such, hypothermia should be established in complex cases where the warm ischaemia time is anticipated to be considerably >30 min.

Our technique of laparoscopic ice-slush hypothermia during LPN consists of: (i) complete mobilization of the kidney; (ii) US-guided tumour identification and circumferential scoring of the renal capsule along the proposed line of resection; (iii) i.v. administration of mannitol (12.5 g); (iv) placing an Endocatch II bag around the kidney with the drawstring closed around the hilum; (v) Satinsky clamping of the *en bloc* renal hilum; (vi) retrieval of the bottom end of the bag outside the abdomen, through an inferior pararectal port site; (vii) opening the exteriorized bag and using pre-loaded syringes to rapidly fill the intra-abdominal bag with ice slurry (600–900 mL) [7] within 4–7 min; (viii) closure of the open end of the bag with a tie and reinserting into the abdomen; (ix) incising open the bag after 10 min (necessary to achieve core renal cooling of 5–19 °C) and removing the ice surrounding only the tumour area; (x) completion of LPN in the usual fashion.

POSTOPERATIVE CARE

Bed rest for 24 h followed by gradual mobilization is advised. The ureteric and Foley catheters are removed on the morning of the second day. The abdominal drain is removed when drainage is <50 mL/day for 3 consecutive days. After discharge, the patient is advised to restrict activity for 2 weeks to prevent potential jarring of the renal remnant. The initial follow-up at 4 weeks includes a physical examination, serum haemoglobin and haematocrit estimates, and serum creatinine measurement. At 3 months, a MAG-3 radionuclide renal scan is taken. Screening for hyperfiltration nephropathy in patients with a solitary remnant kidney includes a 24-h urinary protein measurement. Patients with pathologically confirmed renal cancer have CT and a chest X-ray at 6 months or 1 year.

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Abbreviations: **(O)(L)PN**, (open) (laparoscopic) partial nephrectomy; **US**, ultrasonography.