Partial Resection of the Kidney for Renal Cancer

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Introduction

Partial nephrectomy (PN) represents the gold standard treatment for renal masses <4 cm (cT1a). A few studies support the expanded indication for PN in selected patients with tumors from 4 to 7 cm (cT1b) and larger (cT2) [1, 2].

Indications for partial nephrectomy can be divided in absolute, relative and elective. *Absolute indications* include a localized lesion in solitary kidney, bilateral renal lesions, or poor renal function. *Relative indications* include hereditary forms of Renal Cell Carcinoma (RCC) like Von Hippel–Lindau syndrome, hereditary papillary RCC, Birt–Hogg–Dubé syndrome, or tuberous sclerosis in which there is a high risk of future development of metachronous renal malignancies. Relative indications also exist for patients with unilateral lesion but with the risk of future renal insufficiency such as patients with hypertension, diabetes mellitus, nephrolithiasis or chronic pyelonephritis. *Elective indications* include the presence of renal tumor in patient with normal contralateral kidney [3].

Partial nephrectomy could be performed through traditional open or minimally invasive techniques such conventional laparoscopy and robot-assisted surgery.

Laparoscopic partial nephrectomy (LPN) is a technically demanding procedure with a step learning curve in order to reach acceptable perioperative outcomes as a short warm ischemia time (WIT) and low perioperative complication rates [4]. For this reason the guidelines of the European Association of Urology (EAU) are proposing this approach as an optional treatment for cT1 renal tumors only in highly experienced centers [1].

Robot-assisted partial nephrectomy (RAPN) represents the evolution of the LPN in fact in many specialized centers it has become an integral part of daily practice. The first RAPN series was reported by Getman et al. in 2004 [5]. The robotic technology offers several advantages over the conventional laparoscopy as the better visualization of the surgical field due to superior three-dimensional vision, a wide selection of wristed instruments with 7 degrees of freedom and the elimination of the tremor. This allows the surgeon to perform a very precise resection as the tumor can be approached from all desirable angles, while renorrhaphy can be performed with torque-free suturing simplifying the parenchymal reconstruction and accelerating the manoeuvres to achieve an adequate haemostasis of the

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resection bed [6]. Furthermore it allows the resection of renal tumors greater than 4 cm and those with higher complexity [7, 8].

Lavery and colleagues suggested that prior experience of LPN shortens the learning curve for RAPN in terms of WIT and operative times [9].

Weinberg et al. in a population based study showed that acquisition of a surgical robot is associated with an increased use of nephron sparing surgery (NSS) for renal tumors and also an increase of renal surgery at hospitals with a robot due to referrals from nonrobotic to robotic hospitals [10].

Surgical Technique

Robot Installation

Due to large dimension of the daVinci robotic system, the correct disposition in the OR of the three main components (patient cart, vision cart and console) is essential. For kidney transperitoneal surgery patient cart is placed on the backside of the patient usually with the camera arm at the level of the target anatomy. Right-angle positioning of the robot to the backside of the patient is very important particularly for the Si system. The assistant is positioned on the opposite side of the robot and the assistant beside him on the same side as illustrated in (Fig. 6.1).

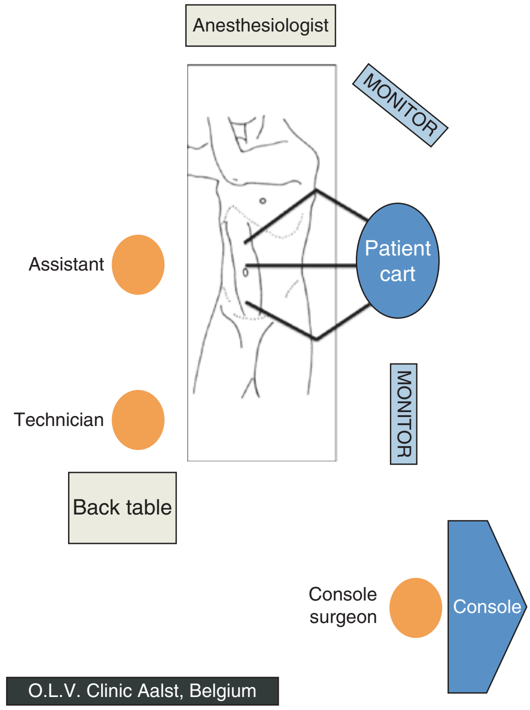

Fig. 6.1 Operating room set-up

Patient Positioning and Port Placement

Patient positioning and port placement are indispensable conditions for a successful accomplishment of the procedure. In robot-assisted surgery the adequate distance between robotic arms and optimal placement of the patient cart beside the patient is essential for a straightforward docking.

Patient is placed in a modified lateral decubitus position with a 20–30° ipsilateral rotation of the shoulder and hip. The anterior abdomen is placed on the lateral edge of the bed to minimize interference with the operative table. Bending of the table at the level of the umbilicus is essential to achieve an adequate working space and avoid collisions between robotic arms. The patient is secured on the table and all pressure points are padded. The complete ipsilateral flank is prepared ad draped (Fig. 6.2).

In our clinical practice the four-arm approach is preferred with the addition of one assistant trocar. We use a medial trocar configuration in which the camera is located medially near the umbilicus. The strengths of this approach include a wide viewing distance and the ability to track instruments being passed into the abdomen by the assistant (Fig. 6.3a). Alternatively, the lateral trocar configuration use a modified trocar arrangement, with the camera port placed more laterally and with two robotic trocars placed medially. This approach provide a closer view of the target structures at the expense of a wider viewing angle (Fig. 6.3b).

The primary access for the pneumoperitoneum is performed using a direct open access checking with the finger the incision of the fascia before the insertion of the trocar loaded with a blunt obturator. During trocar placement a pressure of 12 mmHg is used, while during whole surgery the pressure is adjusted to 5 mmHg in order to perform a low impact surgery. In our experience this

Fig. 6.2 Patient positioning

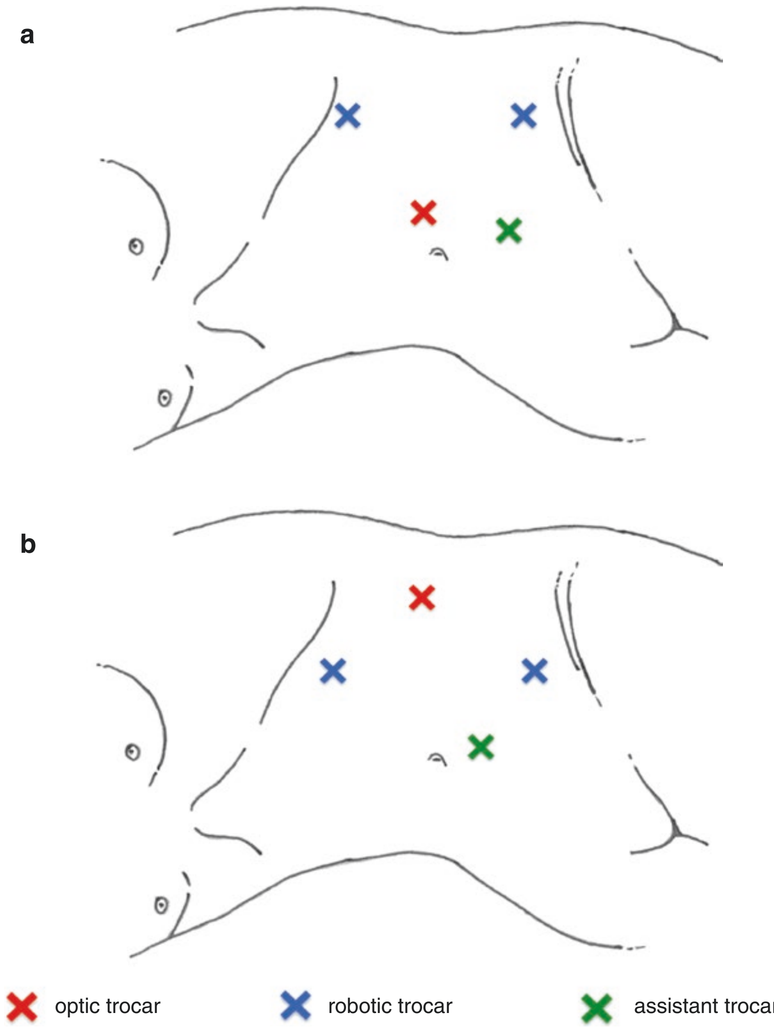

Fig. 6.3 Medial (**a**) and lateral (**b**) camera trocar arrangement

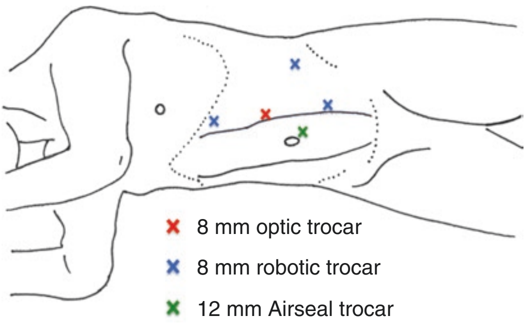

Fig. 6.4 Trocar placement for *left* robotic partial nephrectomy with the Si system

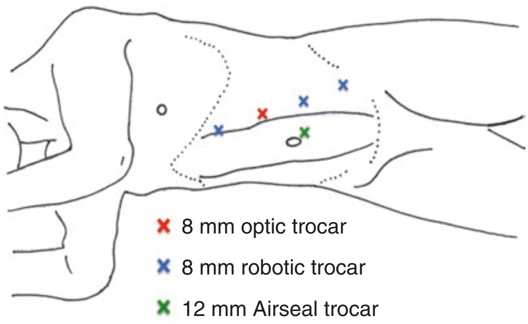

Fig. 6.5 Trocar placement for *left* robotic partial nephrectomy with the Xi system

is feasible in the majority of cases, however in patients with high body mass index the pressure must be maintained on 8 mmHg or above in order to gain a sufficient working space.

Using the Si system the 12 mm camera port is placed 2 cm cranial to the umbilicus on the pararectal line. Once the pneumoperitoneum is achieved additional robotic trocars are placed under direct vision using blunt tips. The cranial robotic trocar is placed subcostally on the pararectal line. The two caudal robotic trocars should be placed carefully to avoid collisions and maintain a sufficient mobility of the robotic arms. The most posterior one is placed approximately 2 cm caudal to the lower pole of the kidney and as lateral as possible. The medial one is placed in the lower quadrant of the abdomen 1 cm lateral from the pararectal line respecting a minimum distance of 8 cm from the previous one. A 12 mm AirSeal assistant trocar is then placed between camera trocar and the caudal robotic arm (Fig. 6.4).

The daVinci Xi surgical platform includes numerous technological enhancements. The patient cart features four robotic arms mounted on rotating overhead boom, which allows almost 360° of rotation and docking from any quadrant. Laser crosshairs on the boom facilitate aligning the patient cart with the camera port and the robotic arms are thinner with additional joints to allow rotation away from the patient (clearance feature). The endoscope has a diameter of 8 mm and can be placed into any working robotic port and finally the autotargeting feature allows the remaining robotic arms to autorotate on the boom to optimize the performance and minimize collisions.

The trocar placement for the Xi system is performed in a linear fashion at the lateral border of the rectus muscle. All the robotic trocars are placed under vision after placement of the Air Seal assistant trocar at the level of the umbilicus and pneumoperitoneum induction (Fig. 6.5).

Robot Docking

The daVinci Si robotic system is driven to the back of the patient with a right-angle positioning to the surgical table. During docking, there are some tricks that can be particularly helpful when using Si system; lifting up the camera arm after docking help to gain space in the operative field, turning inside towards the camera arm the elbow of the lateral caudal robotic arm improve its mobility range in the abdomen and finally moving the third robotic arm over the hip of the patient decrease the probability of external collisions with the caudal robotic arm.

When the Xi patient cart is driven for docking, the laser guidance is activated to facilitate the precise positioning of the rotating boom over the camera port. The camera port is the first to be mounted to the robotic arm and the camera is inserted. The autotargeting allows for optimal robotic arm placement, to maximize access and minimize collisions. After autopositioning, the remaining cannulas are docked and the robotic instruments are inserted. The robotic arms are moved in order to have at least

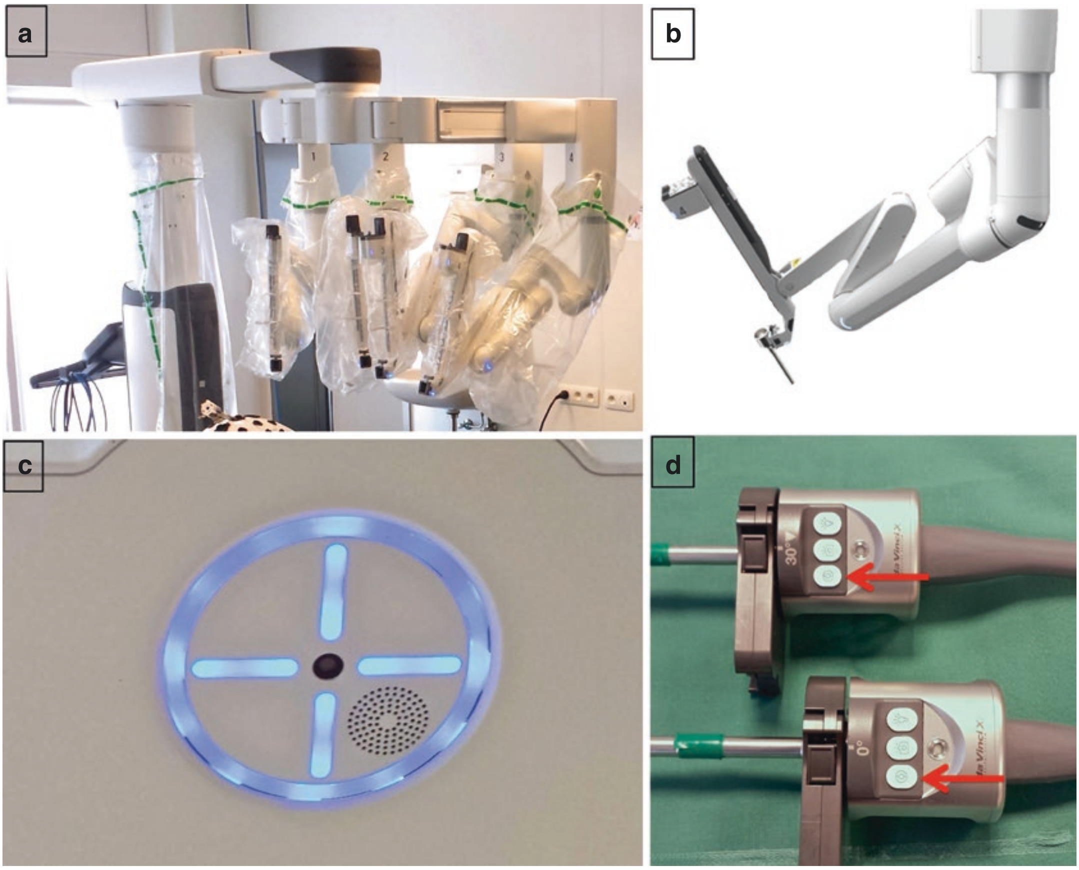

Fig. 6.6 Xi system peculiar features: rotating boom (**a**), additional joint with clearance facility (**b**), laser crosshair (**c**) and 8 mm lens with autotargeting feature (**d**)

the distance of a fist between them. The patient clearance facility could be used to further improve the arm movements (Fig. 6.6).

Conventional Multiport Versus Single Site RAPN

In the past few years, single-site surgery has been adopted to reduce port-related complications, increase recovery time, reduce pain and improve cosmesis [11]. A recent comparative study evaluating multiport versus single-port RAPN revealed significantly better outcomes for standard multiport RAPN in terms of operative time, WIT, and post-operative estimated glomerular filtration rate as well as trifecta outcomes. These findings suggest the limited role of the single-site surgery in RAPN with the current available daVinci platform [12].

Selection of the Robotic Instruments

A 30° lens is used throughout the case. The instruments usually used include a Monopolar Curved Scissors, a ProGrasp forceps and a Large Needle Driver. The large needle driver is often used as a grasper when positioned on the fourth robotic arm.

Transperitoneal vs. Retroperitoneal Approach

RAPN can be performed through a transperitoneal and retroperitoneal approach. Most of the robotic surgeons prefer the transperitoneal approach regardless the anatomical and topographic characteristics of the tumor.

Arguments in favor of the transperitoneal route are the lager working space allowing better maneuverability of the instruments and the more familiar anatomic landmarks improving the orientation of the surgeon. However it requires bowel mobilization and complete isolation of the kidney in case of posterior renal tumors. Bowel irritation due to mobilization and the contact with blood or urine can delay postoperative recovery.

The retroperitoneal approach allows direct access to the posterolateral surface of the kidney, as well as posterior hilar structures. The bowel mobilization is avoided, however the spatial limitations of the narrow retroperitoneal working space may cause disorientation and consequent inadvertent injury. Until now there are no evidences that one approach is preferable to the other and the choice is based on the surgeon's preference [13].

Personal Technique

Isolation of Renal Hilus and Tumor Identification

At our Institution the transperitoneal approach is the first choice. Primary access to the renal hilum is achieved leaving the kidney attached to the abdominal wall. On the right side the renal vein is usually identified following the inferior vena cava under the liver. On the left side the isolation of the renal vessels is performed starting from the kidney lower pole. Renal vein and artery are isolated by placing a vessel loop around them secured with a Hem-o-lok clip (Fig. 6.7). Then the Gerota's fascia is incised and the perirenal fat extensively removed to obtain an optimal tumor visualization and to mobilize the kidney until easy access to the tumor from all sides is achieved. The portion of perirenal fat that is in direct contact with the tumor is left on site to allow a correct pathological staging. Intra-operative ultrasound is not mandatory in the presence of predominantly exophytic neoplasms. It becomes of particular importance for tumors with large endophytic growth and/or hilar location. Robotic ultrasound probes that can be controlled directly by the console surgeon are available and the Tile Pro feature allows the surgeon direct visualization of intraoperative ultrasonographic image onto the console screen (Fig. 6.8). Under ultrasonographic guidance the tumor margin is demarcated using monopolar curved scissors a few millimetres away from the tumor circularly (Fig. 6.9).

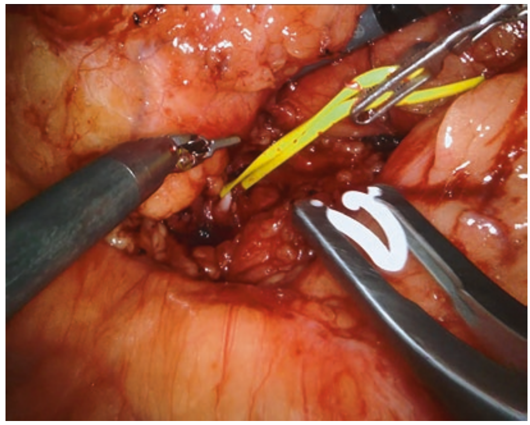

Fig. 6.7 Hilar control. A vessel loops is passed around renal artery and secured with an Hem-o-lok clip

Hilar Control and Tumor Excision

The most classic approach to RAPN involves clamping of the main renal artery until the end of the cortical renorrhaphy in order to reduce blood loss and ensure tumor resection in a bloodless field.

A lot of strategys have been developed and tested in order to eliminate global renal ischaemia and minimize the ischemic damage of the renal remnant. This is of particular importance in patients with relative and even more with absolute indications to PN.

Global renal ischemia time can be significantly reduced by the *early unclamping* of the main renal artery immediately after placement of the inner rennoraphy running suture. In this way the WIT can be reduced by more than 50% with

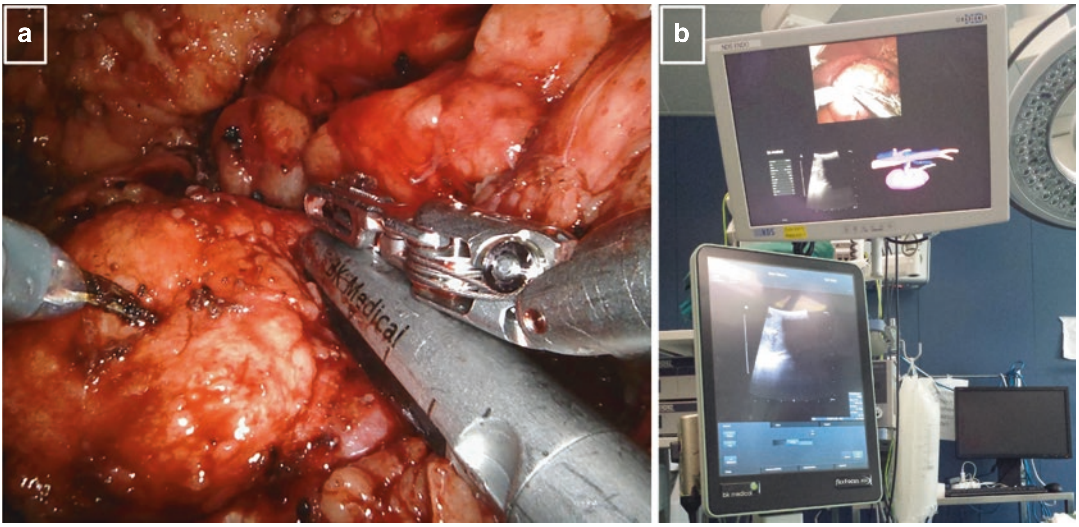

Fig. 6.8 Robotic drop-in ultrasound transducer (**a**) and Tile Pro function on daVinci Xi system (**b**)

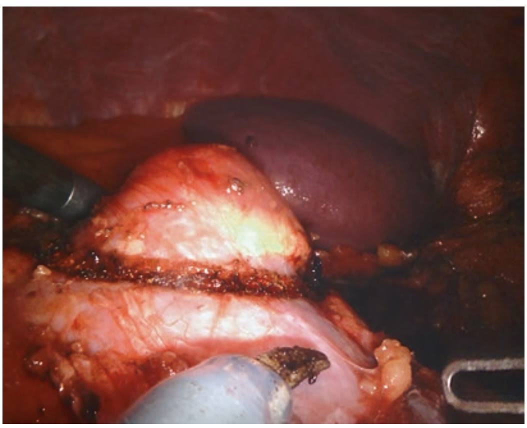

Fig. 6.9 Demarcation of the tumor by intraoperative ultrasound

similar estimated blood loss and bleeding complications [14].

The *selective clamping* technique was primarily used in minimally invasive PN to reduce the ischemic insult that result from clamping of the main renal artery. However in certain distances such as dense or adherent perirenal fat or short segmental arteries is not feasible [15].

If the tumor has favorable anatomic features as small size, exophytic lesion and low nephrometry scores, PN may be performed without any vascular clamping (*off-clamping*). Tumor excision and renal reconstruction are performed completely unclamped [16].

Finally the induction of hypothermia has also been proposed either by transarterial cold perfusion of the kidney or by retrograde ureteral cooling, or more recently by covering the kidney with ice slush during ischemia time [17].

Many surgeons prefer to use mannitol and/or furosemide during PN, however recent studies have shown that there are no significative advantages [18].

The issue of improving renal functional outcomes by decreasing warm ischemia time is not yet settled. Several studies indicate that the amount of renal parenchyma preserved, but not the type or duration of ischemia, is significant in multivariate analysis [19].

In our everyday clinical practice the arterial clamping is achieved using the robotic bulldog clamps. Usually, only the main renal artery is clamped. However, in larger or centrally located tumors, both renal artery and vein are clamped due to the high risk of main renal vessels injury. In selected cases, a selective clamping of secondary or higher-order arterial vessels going to the tumor is performed followed by a perfusion assessment using the fluorescence imaging (FireFly). 1.5–2 mL of indocyanine green (ICG) is injected intravenously and in a few seconds the main renal vessels and the perfused parenchyma are visualized in green with the exception of the area perfused by the clamped higher-order arterial vessel (Fig. 6.10). If the non perfused area corresponds with the tumor, excision can be performed using the selective arterial clamping technique, vice versa the best strategy will be to clamp another higher-order artery or a lower-order arterial vessel or even the main renal artery. Good vision at the level of the resection bed is mandatory to follow the correct dissection plane avoiding the risk of tumor violation and local dissemination.

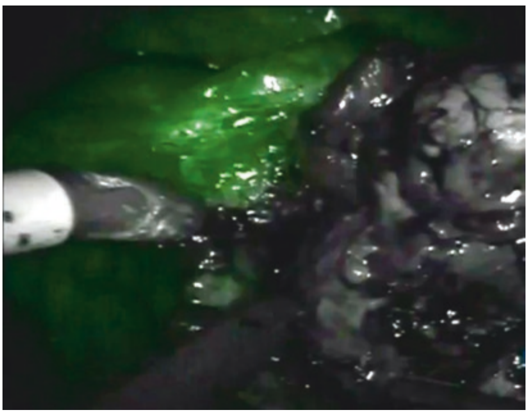

Fig. 6.10 Perfusion assessment using Fire Fly fluorescence imaging shoving the normally perfused parenchima (*green*) and the non perfused area due to selective arterial clamping

The borders of the tumor are defined and the demarcation line is then entered a few millimeters into the kidney cortex with blunt dissection before clamping. Clamping is usually performed with robotic bulldog (Scanlan International) (Fig. 6.11). In case of an off-clamping procedure the tumor excision is performed without bulldog placement.

The tumor excision is performed mainly using cold scissors and ProGrasp forceps are used to gently spread the tissue to aid the dissection (Fig. 6.12). In this way the surgeon can judge the quality of the incised tissue avoiding cutting into the tumor and thus avoiding positive surgical margins. During this step the role of the assistant controlling the suction device is essential. In fact he has to facilitate the tumor excision by gently pushing the parenchyma in order to expose optimally the dissection plane to the surgeon. In case of little opened vessels in the tumor bed the assistant has to perform a gently compression or put a clip. Once the dissection is completed, the specimen is placed above the liver or spleen for an easier later retrieval.

Renal Reconstruction

Renorrhaphy is typically performed with the sliding-clip technique, originally reported by Benway et al. [20]. For the renorrhaphy all sutures should

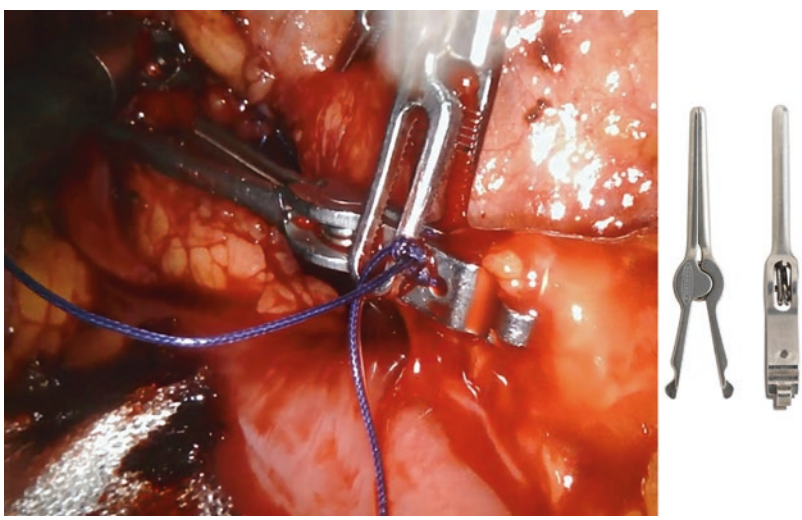

Fig. 6.11 The renal artery is clamped using the bulldog directly by the robotic surgeon

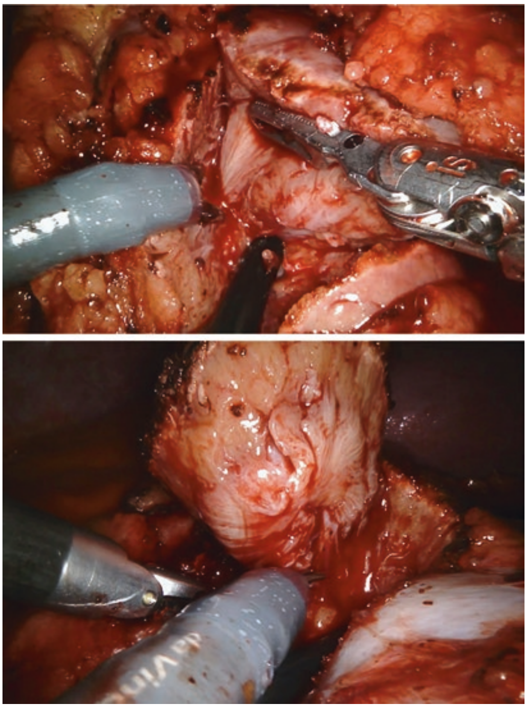

Fig. 6.12 Tumor excision using Monopolar curved scissors on the *left*, ProGrasp forceps on the *right* and Needle holder on the fourth robotic arm

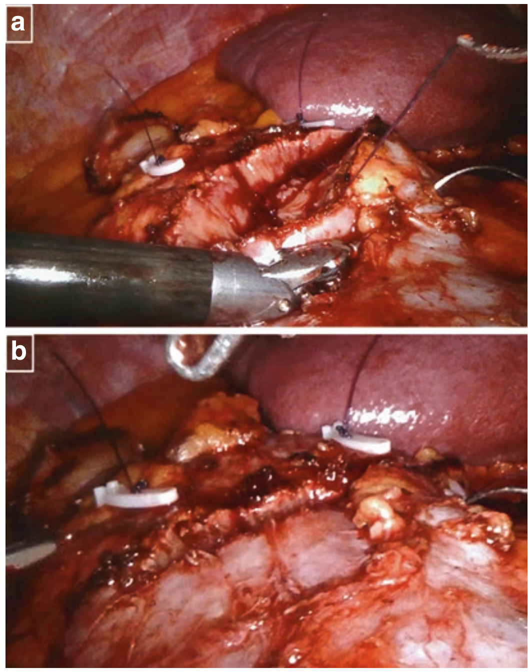

Fig. 6.13 Inner renorrhaphy performed using 3-0 Monocryl running suture

be first prepared on the back table before the beginning of the surgery. A knot is tied at the end of a 18 cm suture and a Hem-o-lok cip is placed above the knot. The robotic monopolar scissors are exchanged for a robotic large needle driver and the inner defect closure is performed with a running Monocryl 3-0 suture preloaded with a Hem-o-lok clip (Fig. 6.13). The suture is brought from outside to inside the parenchyma in order to have the clip outside the defect. Care is taken to close all the retracted calices and vessels with the running suture to avoid further complications. At the same time too deep bites should be avoided in order to prevent injury to deep larger vessels lying just under the defect. The Monocryl suture is then passed from inside to outside through the parenchyma and secured with another Hem-o-lok clip. The combination of monofilament suture and Hem-o-lok clips allow to brought the right tension on this suture and also to further regulate the tension.

After completion of the inner renorrhaphy, usually the bulldog clamp is removed according to early unclamping technique and the kidney is checked for any bleeding.

The outer renorrhaphy is performed using the sliding clip technique with a Polyfilament 1-0 sutures with CT needles (Fig. 6.14). The running suture is used, and at each bite, the thread is secured with a Hem-o-lok clip and proper tension is given on the tissue. After that the inner renorrhaphy is put under tension again, because of the pressure of the outer closure. Using the LapraTy clips this is not possible because an excessive force is needed to move the clip over the suture with the risk of tearing it especially during further regulations of the tension. Finally a second Hem-o-lok clip is placed on all ends of the sutures to prevent involuntary sliding of the previous clips. To minimize the risk of involuntary sliding of the clips is recommendable to "hook" the suture with the clip, which means to place the hook end of the second clip on the suture (Fig. 6.15). If necessary, additional sutures or various fibrinogen coagulation

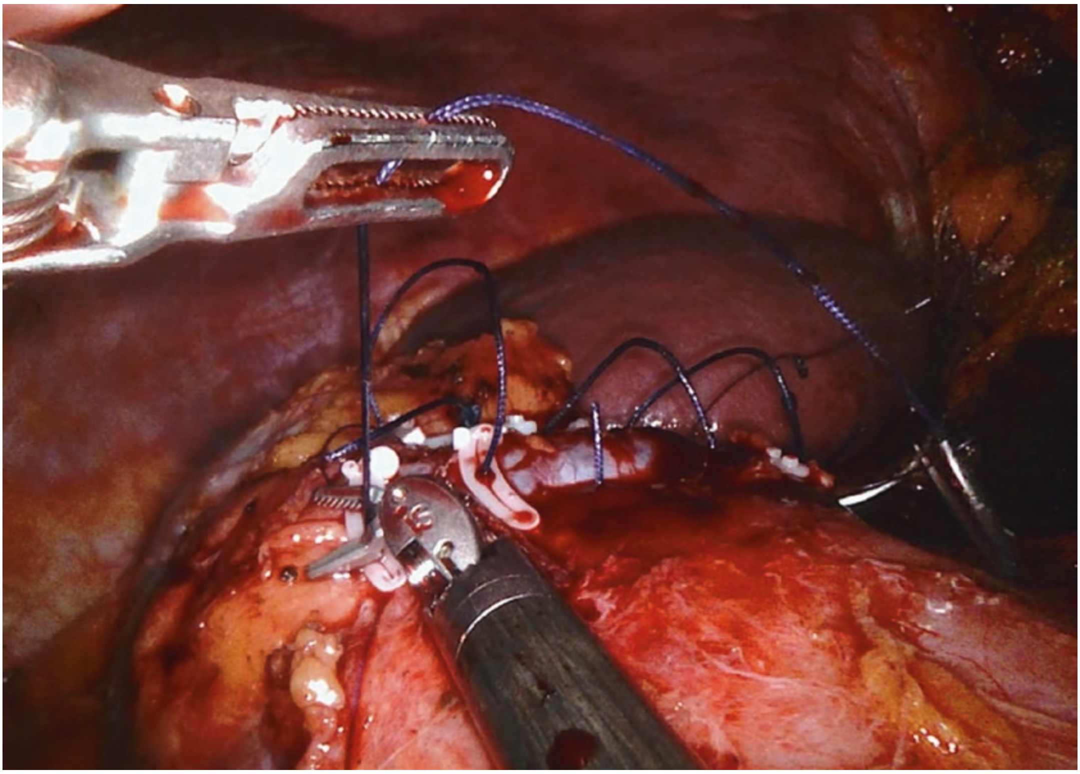

Fig. 6.14 Outer renorrhaphy performed using a Polyfilament 1-0 sutures with CT needles and the sliding clip technique

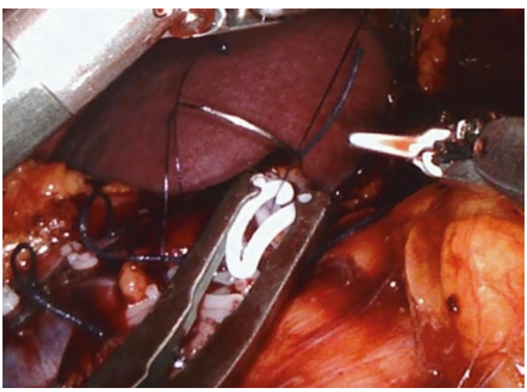

Fig. 6.15 To minimize the risk of involuntary sliding of the clips is recommendable to "hook" the suture with the clip, which means to place the hook end of the second clip on the suture

enhancers and tissue sealants can be applied on the defect. However, their usefulness is still under debate.

The specimen is placed in a retrieval bag and needles, bulldog clamp and vessel loops are removed (Fig. 6.15). Gerota fascia is closed, and the robot undocked. A wound drain is introduced through one of the 8 mm trocars under direct vision. The specimen is usually retrieved through the camera port which may be enlarged if necessary. The fascia at the extraction site is closed with a thick dissolvable suture. The remaining trocar sites do not require fascial closure, as the risk of herniation is low.

Other Approaches

Retroperitoneal Approach

This approach have been described and shown by James Porter during several live surgery procedures.

Patient is placed in a full flank position with the ipsilateral side up relative to the renal tumor. The ipsilateral arm is secured with an airplane-style arm-holder and the dependent arm is padded and secured close to face to avoid conflicts with the robot. The bed is fully flexed to provide maximal space between the ribs and the iliac crest. The anestesiologist is placed far from the patient's head to accomodate docking of the robot over the patient's head. A long circuit is attached from the endotracheal tube to the ventilator to ensure an adequate ventilation of the patient during all anesthetics.

A four-port configuration (one camera trocar, two robotic ports and one 12 mm assistant trocar) is routinely used for retroperitoneal robot-assisted partial nephrectomy (RP-RAPN).

The retroperitoneal space is created by placing a balloon dilator in an incision in the midaxillary line 1–2 cm above the iliac crest. After full expansion the ballon is removed and the 12 mm trocar is inserted for insuflation of the retroperitoneum with 15 mmHg of carbon dioxide. The first 8 mm robotic trocar is placed in the posterior axillary line in a horizontal plane approximately 2 cm cephalad to the 12 mm camera port. A second 8 mm robotic trocar is placed in the anterior axillary line in a horizontal plane approximately 1 cm caudad to the first robotic trocar. After that the peritoneum is reflected 2 cm medially to the anterior superior iliac spine and a 12 mm assistant trocar is inserted at this location. A 0° robotic laparoscope is most commonly used, but on occasion, a 30° up lens is needed to avoid camera conflict with the iliac crest.

The fenestrated bipolar forceps is used to lift the kidney upward to facilitate the dissection through the perinephric fat onto the pulsations of the renal artery. The artery is skeletonized to allow subsequent selective versus nonselective clamping. The renal vein is not routinely dissected out and clamped with the exception of very central renal tumors encroaching on the venous vasculature. Defatting of the kidney begins under the upper Gerota fascia cut edge, which is used as a landmark to avoid inadvertent peritoneotomy (Fig. 6.16).

Fig. 6.16 The excised renal tumor is placed in the endocatch bag

The laparoscopic ultrasound is used to identify and confirm tumor location, and cautery is used to circumscribe the planned renal capsule incision. After clamping the main renal artery or an arterial branch, the tumor is excised with cold scissors. The renal defect is reconstructed by first closing the collecting system, if it is entered. 4-0 absorbable Monofilament is used to repair collecting system and to oversewn individual vessels. The inner renorrhaphy is performed with 3-0 Monofilament absorbable suture in a running fashion and secured on the outside of the kidney with locking clips. The renal cortex is then closed using 2-0 absorbable, braided suture using the sliding-locking-clip technique.

The tumor is placed in an endoscopic entrapment sac and a 15 French round drain is placed through the more anterior 8 mm robotic trocar [21].

Zero Ischemia

Zero ischaemia was introduced as a technique to eliminate the renal ischaemia induced by hilar clamping. This is of particular importance especially for minimally invasive techniques such laparoscopic and robot-assisted partial nephrectomy, where a prolonged WIT is often mentioned as a criticism in comparison with open approach. It was first described by Gill et al. in 2011 in association with controlled hypotension to 60 mmHg of arterial pressure during the excision of the deep part of the tumor [22]. Since then, novel techniques, as early unclamping, off-clamp surgery, segmental arterial clamping, vascular microdissection and other approaches have been developed and tested in order to eliminate global renal ischaemia and maximize function of the renal remnant.

In order to facilitate the resection of medial tumors with zero ischemia laparoscopic or robot-assisted technique the anatomic renal artery branch microdissection have been proposed. The main renal artery and vein are mobilized and individually encircled with mini-vessel loop. Then the hilar microdissection is performed in a medial-to-lateral direction to identify the specific arterial branch or branches supplying the tumor. If necessary a small 1–2 cm radial nephrotomy incision is performed to expose specific arterial branches. Transient test placing a disposable bulldog clamp could be performed to confirm tumor devascularization. In case of hilar tumors that are in contact with renal artery and vein it should be peeled away preserving intact the big vessels. The hemostasis in the PN bed is performed using a combination of clips and intracorporeal suturing. Any pelvic-calyceal opening is repaired with sutures. If needed the arterial pressure may be pharmacologically decreased transiently to minimize renal parenchymal bleeding.

A precise understanding of the renal anatomy and vascularization is mandatory before proceeding with the surgery. Bi- or triphasic contrast-enhanced CT of the abdomen with slice thickness of 5 mm or less is the reference standard to delineate the relationship of the mass to adjacent normal structures and demonstrate the vascularization of the tumor. Three-dimensional CT reconstructions of the renal mass and vascularization are very useful for the surgeon to guide PN surgery, especially in complex cases. In fact they allow to reliably predict the tumor proximity to vascular structures and collecting system (Fig. 6.17).

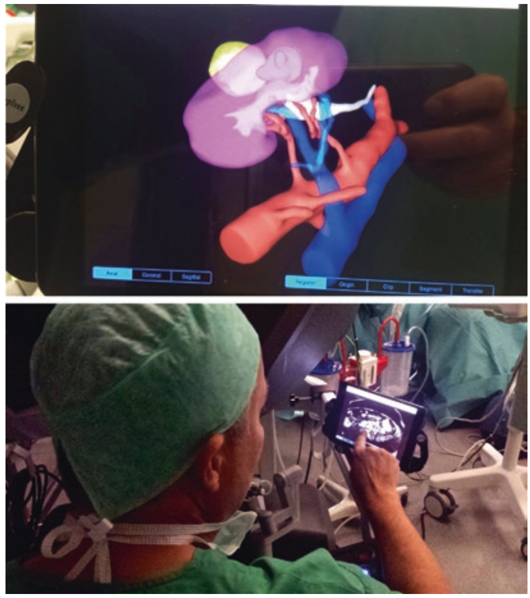

Fig. 6.17 3D reconstructions allow to reliably predict kidney vascularization and the conformation of the tumor

Also in our experience the number of RAPN performed with zero ischemia technique is growing even for complex and medial tumors.

Perioperative Outcomes

Since Gettman and colleagues published the first RAPN series in 2004, several case series and comparative studies have been published suggesting promising results.

Dulabon et al. in a large multi-institutional series of 446 patients with 41 hilar and 405 nonhilar tumors, reported a mean operative time of 196 and 187 min, a mean WIT of 26.3 and 19.6 min, a mean estimated blood loss of 262 and 208 mL and a mean hospitalization of 2.94 and 2.87 days respectively. Complication and conversion rates were 5.2 and 2.2% and perioperative transfusions were 2.4 and 4.2% for the hilar and nonhilar tumor cohort respectively [23].

It has been suggested that prior robotic experience with the robotic platform is important for successful application of RAPN. Mottrie at all demonstrated that, in the hands of an expert robotic surgeon dealing with other robotic procedures, RAPN is safe, requiring a short learning curve to reach satisfying results in terms of WIT, console time, blood loss, and complication rates. The WIT <30 min was reached after the first 20 cases and a WIT <20 min after the first 30 procedures. In this single-centre series, they observed only 2 (3.2%) grade 3 complications according to Clavien classification [6]. Paulucci and colleagues in a multi-institutional study concluded that although RAPN can consistently be performed safely with acceptable outcomes after a small number of cases, improvement in trifecta achievement, WIT, EBL, blood transfusions and a shorter hospitalization continues to occur up to 300 procedures [24].

More recent studies showed a further significant improvement in the peri-operative outcomes after RAPN and the feasibility of this new approach also in complex cases.

Ficarra et al. in a recent multicentric, international study analyzed retrospectively the clinical records of 349 consecutive patients and reported a median WIT and console time of 20 and 120 min respectively in patients with intermediate and high-risk tumors according to PADUA score [25].

Currently, in our experience, the operative time ranges between 80 and 120 min, the median WIT using the early unclamping technique is 9 min (range 5–15 min) and estimated blood loss between 100 and 150 mL. The overall complication rate resulted 21% with 8% of Clavien grade ≥2 and 3% of grade ≥3 complications. No positive surgical margins were observed after the first 62 patients analysed to evaluate the learning curve period [6].

In our everyday practice we use early unclamping technique in most of the cases. When feasible a selective clamping of higher-order arterial branches is performed, however this approach may result complex requiring long operation time also in hands of a very expert robotic surgeon. Recently the number of cases performed without any vascular clamping is increasing due to a better patient selection and advanced preoperative imaging as the 3D computed tomography reconstructions and patient-specific tissue-like 3D-print kidney models created with advanced three dimensional printing technology (Fig. 6.18).

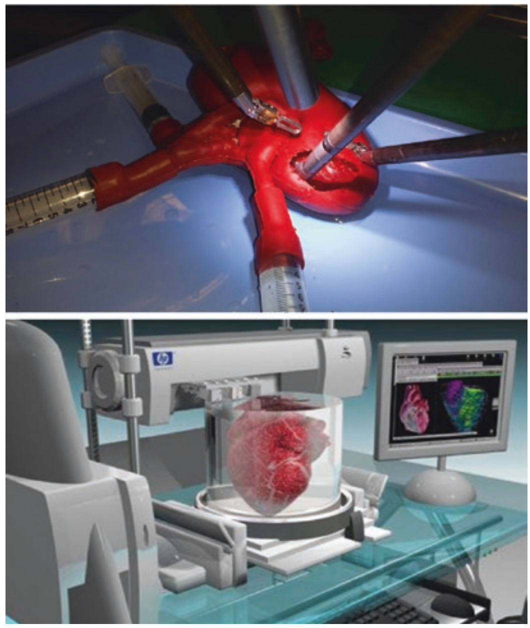

Fig. 6.18 Specific tissue-like 3D-print kidney models created with advanced three dimensional printing technology

Few data are available about the application of RAPN in the treatment of >4 cm tumors.

Two recent studies investigate the feasibility of RAPN on T1b renal tumors comparing the trifecta and pentafecta rates between T1a and T1b renal masses. They roled out that the rate of pentafecta after RAPN was comparable between T1a and T1b renal masses [26] and that RAPN allows significantly lower WIT and estimated blood loss with higher rate of trifecta achievement compared with LPN [27].

Petros et al. in a series of 83 patients with mean tumor size of 5 cm reported a mean operative time, blood loss and WIT of 177 min, 200 mL and 24 min respectively with low risk of intra-operative and post-operative high-grade complications (0% and 8% respectively) [28].

In a recent metaanalysis authors ruled out that PN is a viable treatment option for larger T1b and also T2 renal neoplasms, as it offers acceptable surgical morbidity, equivalent cancer control, and better preservation of renal function, with potential better long-term survival than radical nephrectomy. They concluded that for T2 tumors, the use of PN should be more selective, and a higher risk of perioperative complications should be taken into account [2]. However the role of minimally invasive PN for T2 renal tumours is not yet known.

Studies comparing RAPN to LPN showed a significant shorter WIT in the RAPN groups. Moreover, some studies documented a statistically significant advantage in favour of robotic procedure also in terms of reduction of blood loss and in-hospital stay duration [29].

Ficarra et al. showed that RAPN can attain equivalent perioperative and functional outcomes as OPN in patients with cT1 renal tumors, being a less invasive approach and offering a lower risk of bleeding and postoperative complications. However, the OPN is associated with a shorter WIT and a higher percentage of unclamped procedures. The overall renal function evaluated at 3 months after surgery seemed to be equivalent between the approaches [30].

Functional and Oncologic Outcomes

Available functional outcomes indicated excellent preservation of renal functional reserve after RAPN. However, the majority of these studies are based on the evaluation of creatinine levels (mg/dL) and/or estimated glomerular filtration rate (eGFR) values. Therefore, the real impact of the surgery on the renal function could be masked by the normal contralateral kidney function. Only a few studies evaluated the renal function of the treated kidney after RAPN using the renal scintigraphy. Zagar et al. studied the individual renal unit function after RARP in a cohort of 99 patients with the aid of nuclear renal scan. They ruled out that the ipsilateral renal function preservation was significantly lower than total eGFR preservation (72% vs. 83.83% respectively) and that baseline renal function, BMI, WIT >30 min and the amount of resected healthy renal parenchyma represent the factors with a significant impact [31].

Considering the short follow-up reported in the majority of available series, only early and intermediate oncologic outcomes can be evaluated after RAPN. In literature, in most recent series the risk of positive surgical margins (PSM) ranges between 2 and 4%. This preliminary results can be considered overlapping with the percentages previously reported after open or traditional laparoscopic partial nephrectomy.

Khalifeh et al. reported intermediate-term oncologic and functional outcomes on a series of 134 patients. The overall survival (OS) was found to be 97.0% at 3 years and 90.2% at 5 years, while the cancer-free survival (CFS) was 98.9% at 3 years and 5 years. With only one renal cell carcinoma (RCC) recurrence the OS and CFS at 3 and 5 years were comparable to similar studies describing laparosocopic, open and radical nephrectomy [32]. In another study with a multi-institutional cohort of 943 patients, the same authors reported a PSM rate of 2.2% and a 5-year recurrence-free and metastasis-free survival of 94.8% and 97.5% respectively with a mean follow-up of 64 months [33].

Complications and Management

Complication rates can be used to evaluate the safety of novel surgical procedures. Initial RAPN series reported complication rates from 0 to 20% and notably higher complication rates were demonstrated for tumors of increasing complexity.

Hemorrhagic complications are among the most common and can rappresent potentially life-threatening during PN requiring immediate treatment with blood transfusions, interventional embolization or operative reexploration.

Urinary leak is also a common complications after RAPN. It can be prevented by close inspection of the resection bed and accurate closure of the calycs during inner renorrhaphy. In case of a postoperative recognition of a urinary leak the decompression of the urinay tract is indicated in order to maximize healing of the collecting system.

Promt recognition of bowel injury is essential to avoid future severe complications. If a small laceration is noted, it can be repaired intraoperatively with a 4-0 Vicryl suture. In case of a larger laceration, it may require bowel resection and necessitates general surgeon involvement.

Rhabdomyolysis may occur due to compression at pressure points related to patient positioning on the operating table. Male sex, high body mass index, prolonged operative times and lateral decubitus position are all risk factors. Serum creatinine phosphokinase and creatinine should be trended to follow the clinical course. Management includes intravenous fluid hydration and if a compartment syndrome occurs, fasciotomy may be necessary.

Renal insufficiency (RI) due to nephron loss is significantly reduced with partial versus radical nephrectomy. In case of a postoperative RI close monitoring of urine output and serum creatinine should be performed. A postrenal etiology including clot obstruction must be roled out and if renal function further deteriorates or persists, a nephrology consultation should be asked.

Tanagho et al. performed a multi-institutional analysis of complications in 886 patients undergone RAPN at five high volume United States centers. Intraoperative complications occurred in 23 patients (2.6%) and 139 postoperative complications occurred in 115 patients (13.0%) for a total complication rate of 15.6%. Most (77.0%) were Clavien grade 1 and 2 and were managed conservatively [34].

At our institution we recorded an all grade complication rate of 21% with only 3% of Clavien grade 3 and no grade 4-5 complications.

Conclusions

Robot-assisted partial nephrectomy (RAPN) represent the evolution of conventional laparoscopy with the advantage of a new sophisticated technology. The improved vision associated with wristed instruments allows a decreased ischemia time, which is basically related to the length of the tumor dissection and suturing phase. Furthermore allows average surgeons with or without previous laparoscopic experience to overcome the learning curve in a reasonable time. It allows us to operate more comfortable on complex tumors respecting the oncologic principles and preserving as much renal function as possible. As reported by some Authors, it allows also to manage large and complex renal masses, including endophytic, central, and hilar lesions. Today a major problem remain the costs related to this technology. Maybe in the future, with the advent of new robotic systems from different companies, the costs will progressively decrease.

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