Partial Resection of the Kidney for Renal Cancer

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3.1 Introduction

Partial nephrectomy (PN) can be used in patients with bilateral tumours or with anatomic or functional solitary kidney to avoid dialysis (imperative indication) or in patients with normal contralateral kidney to prevent chronic kidney disease and to reduce non-cancer mortality (elective indication). Consistent peri-operative and oncologic data support the current role of PN as the gold standard of treatment for renal masses ≤4 cm (cT1a). Similarly, a few studies support the expanded indications for PN in selected patients with tumours ranging between 4.1 and 7 cm (T1b). Open PN (OPN) is still considered the best available approach. However, in the last decades, pure laparoscopic (LPN) and robot-assisted partial nephrectomy (RAPN) represent the main alternatives to OPN [1].

LPN is considered a technically challenging procedure requiring a long learning curve in order to reach acceptable warm ischemia time (WIT) and peri-operative complications. For this reason, the European Association of Urology (EAU) guidelines propose such a minimally invasive approach as an optional treatment for cT1a renal tumours only in experienced centres [1]. Conversely, RAPN seems to be a promising procedure, able to bridge the technical difficulties of LPN in favour of a broader diffusion of minimally invasive treatment of small renal masses. Indeed, RAPN can be considered the natural evolution and simplification of traditional LPN, and the advantages offered by the da Vinci platform could be more relevant in a very delicate organ such as the kidney, where every minute WIT lost could be detrimental to renal function. Specifically, three-dimensional (3D) vision, optical magnification up to ×12 and the patented EndoWrist (Intuitive Surgical, Sunnyvale, CA, USA) technology allow robotic surgeons to perform very precise tumour resection with an adequate margin of resection, simplifying the manoeuvres to achieve haemostasis and parenchyma reconstruction and thus reducing WIT. This makes the technique very tempting and adaptive to duplicating the oncologic outcomes of open PN, even in patients with tumours >4 cm or in very complex cases according to the anatomical and topographic characteristics. In experienced centres, RAPN can be indicated also in the treatment of cT1b and in very selected cT2 tumours.

3.2 Surgical Technique

3.2.1 Personal Technique

The majority of robotic surgeons prefer the transperitoneal approach to perform RAPN regardless

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of the anatomical and topographic characteristics of the renal tumours. Arguments in favour of transperitoneal approach are larger working space allowing better manoeuvrability of instruments and more familiar anatomic landmarks improving the orientation. However, this route requires bowel mobilization to expose the kidney, and it could facilitate bowel irritation due to the contact with blood and sometimes with urine. Moreover, posterior renal tumours may be difficult to approach, and full kidney mobilization is required to visualize the lesion. Potential benefits of a retroperitoneal approach could include a more direct access to the kidney and renal hilum without bowel mobilization and an easier approach to the lesions located at the level of the posterior face of the kidney. Conversely, the main issue can be represented by the limited retroperitoneal space making the procedure technically more challenging. No study has compared the two approaches using the robotic technology. Therefore, the choice of the best route should be based on the surgeon's preference. In our experience, we are more comfortable to use the transperitoneal approach.

3.2.2 Patient Positioning and Trocar Placement

Patients are placed on the operation table in a full flank position with the table slightly bent so that the margin between the costal and the iliac crest is enlarged in order to gain space for the robotic arms and lower the risk of collision. The positioning of the patient depends on the tumour location. In detail, a classical half flank position is used for tumours located at level of the anterior face of the kidney. Conversely, a full flank position is preferred for tumours located on the posterior face. To avoid conflict with the robotic arms, the patient arm ipsilateral to the tumour side can be positioned and fixed along the superior margin of the body. The patient is secured to the table, and all pressure points are padded.

In our experience, primary access for the pneumoperitoneum is performed using a direct open access checking with the finger the incision of the fascia and then putting directly the 12-mm camera port loaded with a blunt obturator. This manoeuvre is safe, simple and not associated with some potential risks using the Veress needle. A four-arm approach is actually preferred. We use a medial trocar configuration in which the camera is located medially near the umbilicus. In details, one 12-mm camera port is placed 2 cm cranial to the umbilicus on the pararectal line. The 8-mm cranial robotic trocar is placed subcostally on the pararectal line. Using the four-arm technique, the correct placement of the two caudal robotic trocars is of paramount importance to avoid collision of both arms on one side and to maintain their sufficient mobility on the other hand. This is done under visual control: the most posterior trocar is placed 2 cm caudal to the lower pole of the kidney and as lateral as possible. Now, the fourth robotic trocar is placed in the lower quadrant of the abdomen just 1 cm lateral to the pararectal line with sufficient distance to the former (>8 cm). Usually, only one 12-mm assistant trocar is placed between camera trocar and the cranial or medial caudal robotic arm. If necessary (fatty patients, large liver, difficult cases), an additional 5-mm or 12-mm assistant trocar can be placed on the midline between the camera port and the caudal robotic trocar. The strengths of the medial trocar configuration include a wide viewing distance and the ability to track instruments being passed into the abdomen by the assistant (Fig. 3.1)

Alternatively, other centres use a modified trocar arrangement, with the camera port placed more laterally and with two assistant ports placed medially (i.e. lateral trocar positioning).

The da Vinci robot is docked from backside of patient with an angle centred along the line defined by the camera port and the renal hilum. While docking, there are some tricks that can be particularly helpful: (1) Lift up the camera arm after docking to gain space. (2) The elbow of the lateral caudal robotic arm (nr. 2) must be turned inside towards the camera arm to improve the mobility range of this arm in the abdomen. (3) The third robotic arm is placed over the hip of the patient. Good bending of the table helps to do so without collision to the body. That is why the use of a hip holder is to be avoided as well. A 30° downward lens is used throughout the case. The working

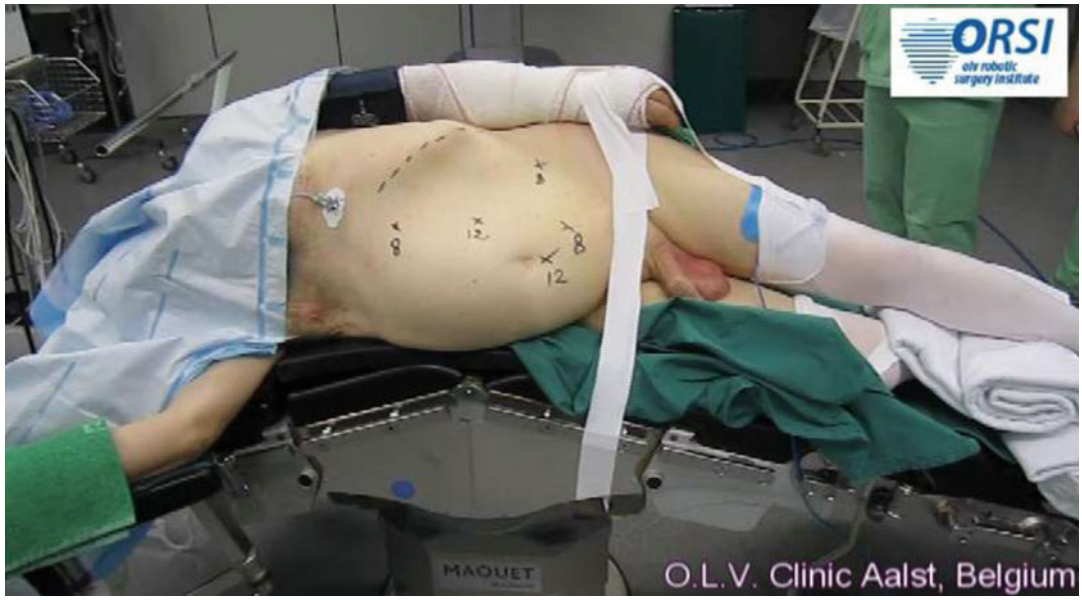

Fig. 3.1 Patient positioning and port placement for 4-arm da Vinci Partial Nephrectomy (O.L.V. Clinic Aalst, Belgium)

arms are outfitted only with robotic monopolar scissors, ProGrasp forceps and needle drive.

3.2.3 Isolation of Renal Hilus and Tumour Identification

Primary access to the renal vessels is achieved, leaving the kidney attached to the abdominal wall. The bowel is reflected medially to expose the retroperitoneum. For right-sided tumours, the renal vein is usually identified following the inferior vena cava under the liver. Conversely, for the left-sided tumours, the renal vessel isolation is conducted starting from the lower pole of the kidney. Renal vein and artery are isolated by placing a vessel loop around them secured with a Hem-o-lok clip (Teleflex Medical, Research Triangle Park, NC, USA). Renal artery branches directed to the tumour can be isolated with the aim of selective clamping (Fig. 3.2). Then, the Gerota's fascia is incised and the peri-renal fat tissue extensively removed to visualize the tumour and to mobilize the kidney until easy access to the tumour from all sides is achieved. To allow a correct definition of the pathologic stage, the peri-renal fat is left on top of the tumour. This step of the procedure is very important to create an ideal situation to minimize the request time for tumour resection and renorrhaphy. Intra-operative ultrasound is then employed to define the gross margins of the mass and to correctly perform the lesion demarcation. Care is taken to free >1 cm of capsule around the tumour, and the parenchyma is incised few millimetres away from the tumour to demarcate the lesion before starting with warm ischaemia (Fig. 3.3). Patients are given intravenous 12.5 g of mannitol about 5–10 min before vascular clamping to reduce ischemic injury.

3.2.4 Hilar Control and Tumour Excision

Clamping is achieved using the robotic bulldog clamps (Fig. 3.4). Usually, only the main renal artery is clamped. However, in larger or centrally located tumours, both renal artery and the vein are clamped. In selected cases, it is possible to perform selective clamping of the secondary or tertiary arterial vessels going to the tumour. In this

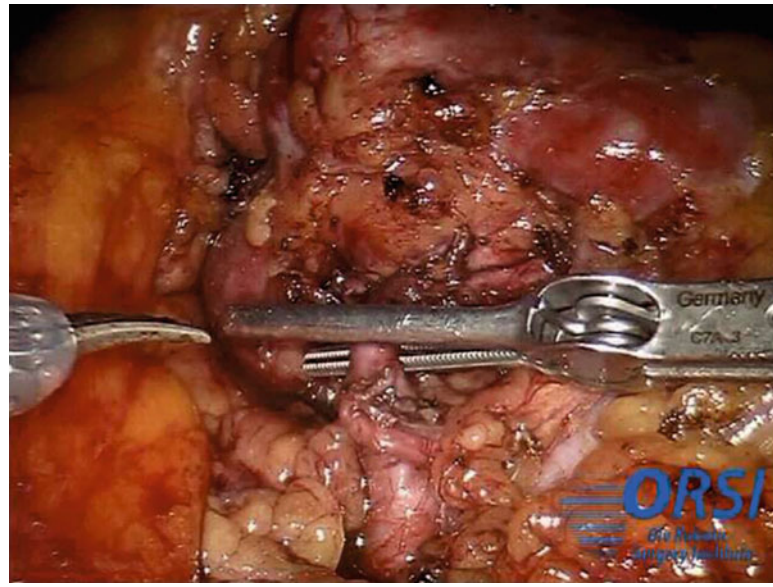

Fig. 3.2 Isolation of secondary renal artery for selective clamping (O.L.V. Robotic Surgery Institute)

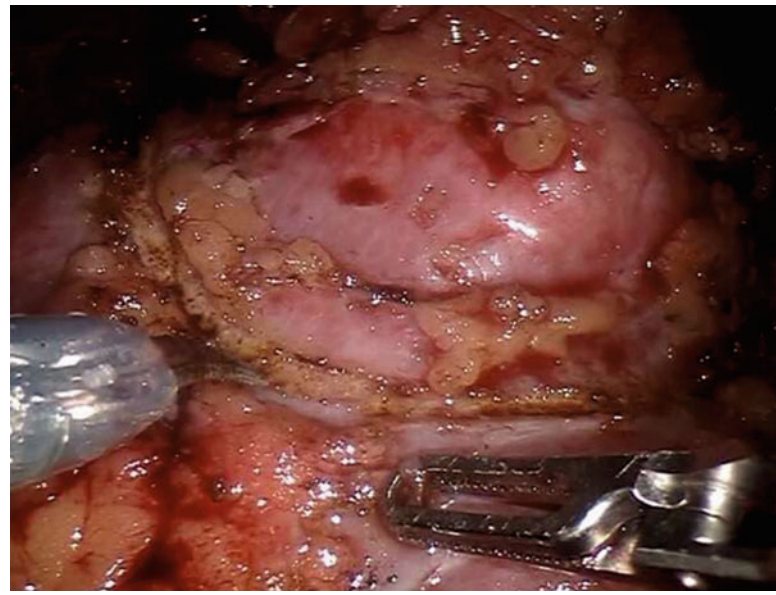

Fig. 3.3 The renal parenchyma is incised few millimetres away from the tumour to demarcate the lesion before to start with warm ischaemia

case, a perfusion assessment using the *FireFly* fluorescence imaging can be performed. In details, 1.5–2 ml of indocyanine green (ICG) is intravenously injected, and the branch of the renal artery clamped. Few seconds after the injection, the main renal artery and vein are visualized in green using the FireFly (near infrared) imaging (Fig. 3.5). Then, the normally perfused parenchyma will appear green with the exception of the area perfused by the clamped secondary or tertiary arterial vessel (Fig. 3.6a, b). If the area surrounding the tumour is not perfused, the tumour excision can be performed using the selective arterial clamping without the risk of excessive bleeding. Vice versa, the risk of bleeding will be consistent, and the best strategy will be to clamp the main artery. Good vision at the level of the bed of the tumour is essential to follow the correct plane of dissection avoiding the risk of tumour violation and local dissemination. Before starting

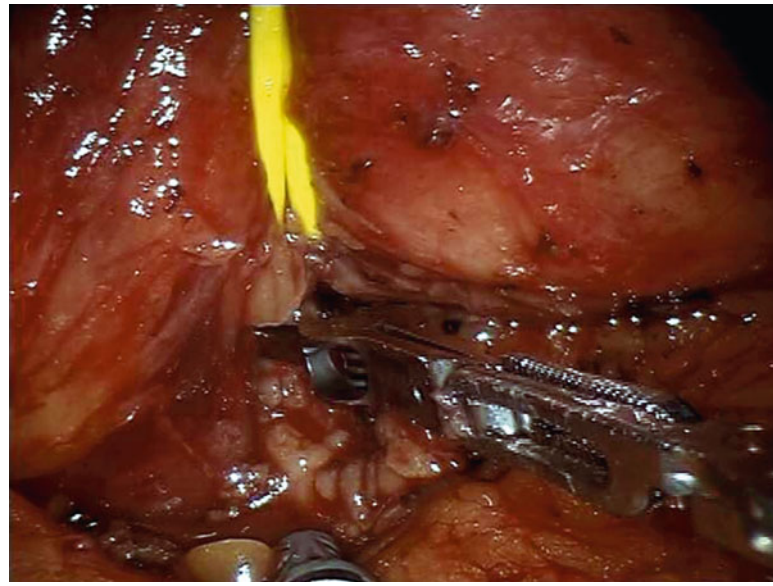

Fig. 3.4 The renal artery is clamped using the bulldog scanlan directly by the robotic surgeon

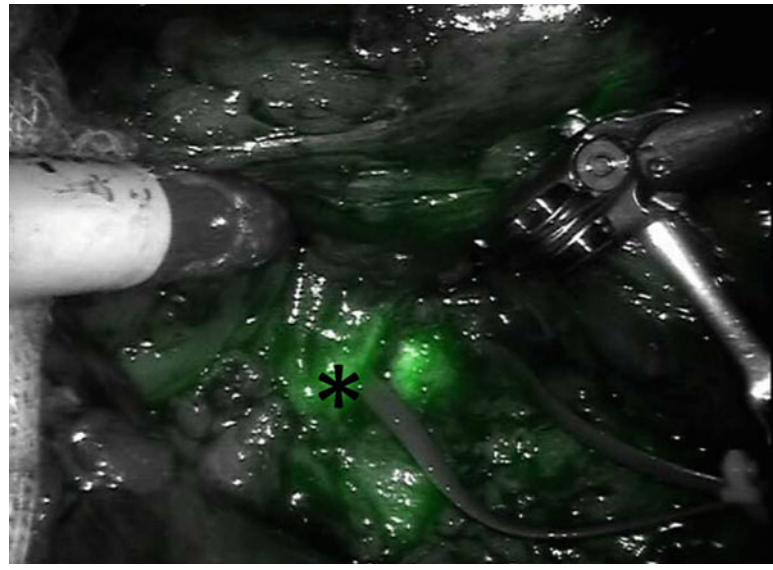

Fig. 3.5 FireFly Fluorescence Imaging showed the renal artery (isolated by placing a vessel loop around) and the renal vein (*)

with the resection, the pneumoperitoneum pressure is increased from 15 to 20 mmHg. Before clamping, the capsule is demarcated a few millimetres away from the tumour circularly. The borders of the tumour can more easily be defined using intra-operative ultrasound. The parenchyma is then entered a few millimetres, which eases blunt resection of the tumour surrounded with a few millimetres of healthy tissue ("enucleoresection"). Clamping is usually performed with one laparoscopic bulldog on each vessel. The ProGrasp forceps can be used to gently spread the tissues to aid dissection. Cold dissection is used so that the surgeon can judge the quality of the incised tissue avoiding cutting into the tumour and thus avoiding positive surgical margins (Fig. 3.7). The role of the assistant controlling the suction device is essential as he has to facilitate the tumour excision by gently pushing the parenchyma and/or compressing little opened vessels in the tumour bed. Once dissection is complete, the specimen is placed above the liver or spleen for later retrieval.

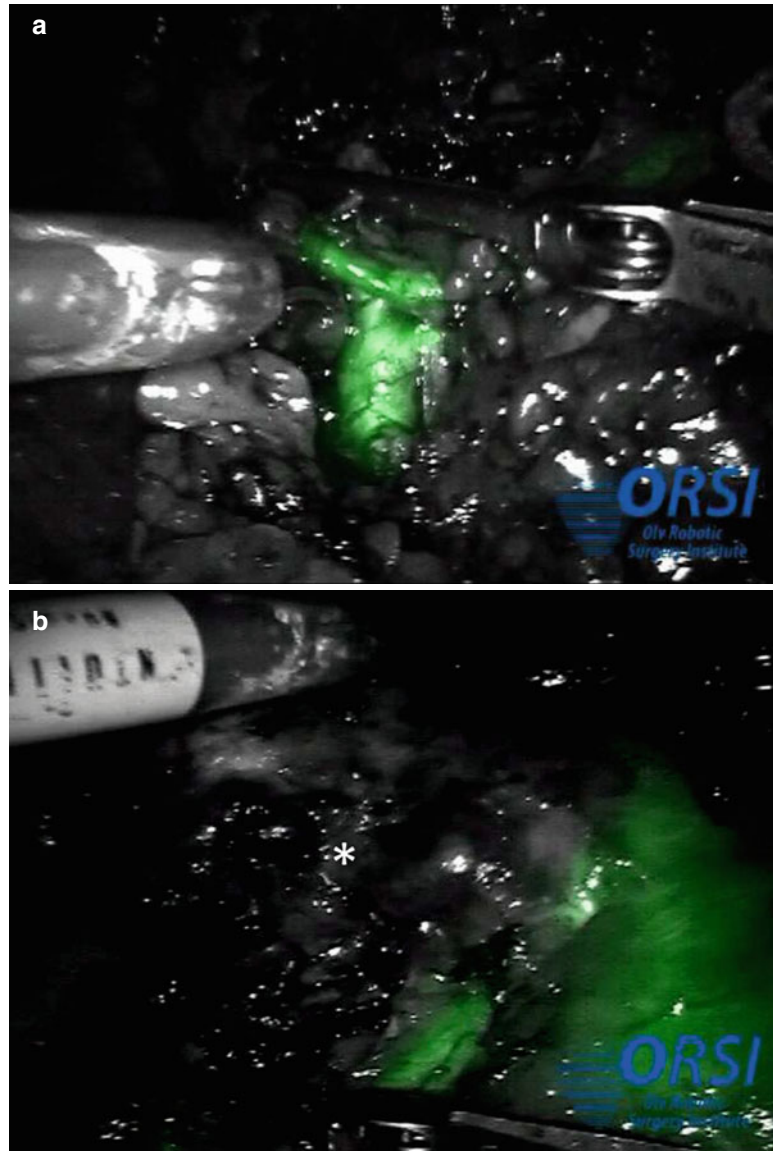

Fig. 3.6 (**a**) FireFly Fluorescence Imaging during selective clamping of secondary arterial branch. (**b**) FireFly Fluorescence Imaging showed the normal renal parenchyma in *green*. The tumour region (*) is not fluorescent because of it is not vascularized after selective clamping (O.L.V. Robotic Surgery Institute)

3.2.5 Renal Reconstruction

For the renorrhaphy, all sutures (Monocryl 3-0 SH Plus and Vicryl 1 CT Plus) are first prepared on the back table. A knot is tied at the end of an 18-cm suture. Above the knot, a Hem-o-lok clip is placed. The robotic scissors are exchanged for a robotic needle driver. The inner defect is closed with a running Monocryl 3-0 suture preloaded with a Hem-o-lok clip. The Monocryl is brought outside in, in order to have the clip outside the defect. Care is taken to take all retracted calices and vessels in the running suture. In contrast, too deep bites should be avoided in order to avoid injuries to larger vessels lying just under the defect. The Monocryl suture is then brought inside out through the parenchyma and secured with a second Hem-o-lok clip. Through the sliding clip technique, the right tension is brought on this suture. Proper tension has been applied when the surface of the kidney is slightly dimpled. After completion of the inner suture, usually the hilar clamping is removed ("early unclamping technique"), the pneumoperitoneum pressure lowered to 12 mmHg and the kidney checked for any bleeding (Fig. 3.8).

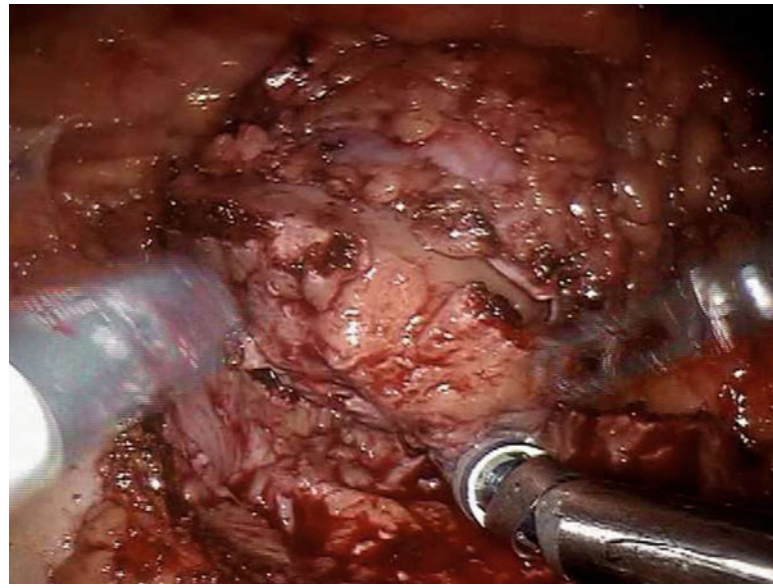

Fig. 3.7 Tumour excision was completed. In this case the procedure was performed. Using the dual console and the robotic suction device

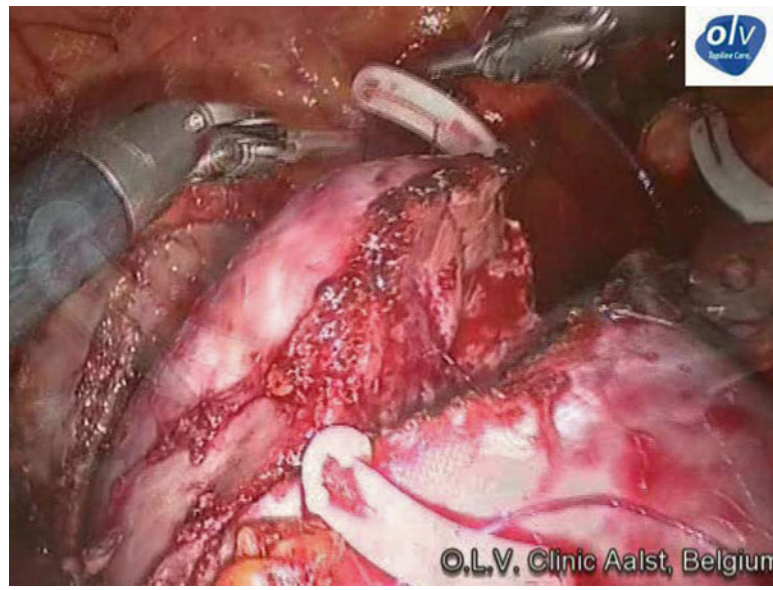

Fig. 3.8 Inner suture is performed using Monocryl 3-0 SH Plus (O.L.V. Clinic Aalst, Belgium)

The outer renorrhaphy is performed with polyfilament 1-0 sutures on CT needles using a running sliding clip technique (Fig. 3.9). The running suture is used, and at each bite, the thread is secured with a Hem-o-lok clip and proper tension given on the tissue. Then, the inner defect suture is put under tension again, because the pressure was taken away as a result of the outer closure. Then, a second Hem-o-lok clip is placed on all ends of the sutures. The use of monofilament suture and Hem-o-lok clip without LapraTy clip allows us to perform this manoeuvre, avoiding application of excessive force. If necessary, additional sutures or thrombogenic material may be used at the level of the parenchyma defect.

The specimen is placed in a retrieval bag, and the needles, bulldog clamp and vessel loop are removed. Gerota's fascia is closed, and the robot

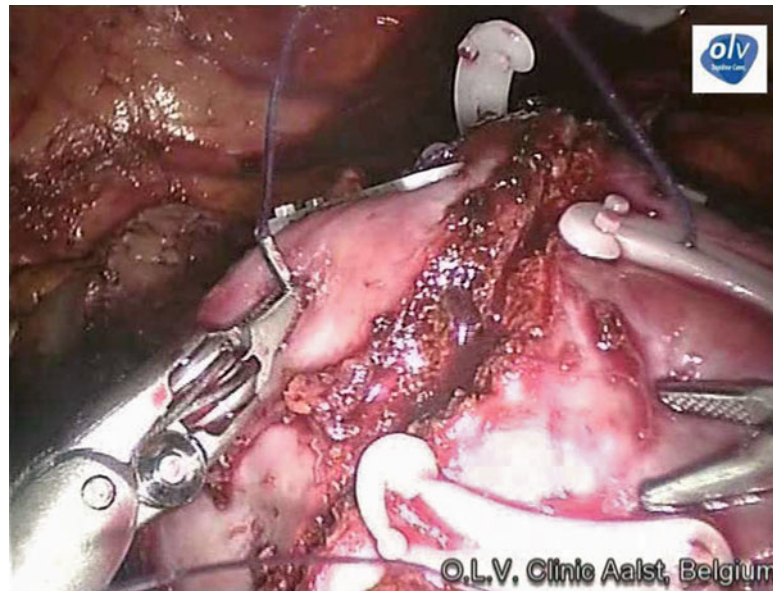

Fig. 3.9 The borders of the parenchyma defect are closed with polyfilament 1-0 sutures on CT needles using a running sliding clip technique (O.L.V. Clinic Aalst, Belgium)

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 should be closed with a thick dissolvable suture. The remaining trocar sites do not require fascial closure, as the risk of herniation is low.

3.3 Other Approaches

3.3.1 Retroperitoneal Approach

This approach is described and shown by James Porter during several live surgery procedures. Patients are placed in the full flank position, and the bed is maximally flexed. The retroperitoneal space is created by placing a balloon dilator (Covidien, Mansfield, MA) in an incision in the mid-axillary line 2 cm above the iliac crest. Once the retroperitoneal space has been dilated, a 12-mm Hasson balloon trocar (Covidien, Mansfield, MA) is placed. The CO_2 pressure is maintained between 12 and 15 mmHg depending on the patient. A four-port configuration (one camera trocar, two robotic ports and one 12-mm assistant trocar) is routinely used for RP-RAPN. Once the ports are placed, the robot is docked by bringing the robot in over the patient's head, parallel to the spine. 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 renal vessels are then exposed, and enough artery is dissected to allow bulldog clamps to be placed on the artery. The vein is isolated, but only clamped if the tumour is large or centrally located. The renal mass is then isolated, and enough parenchyma is exposed to allow a resection margin around the tumour and closure of the defect. Laparoscopic ultrasound is used by the bedside assistant to determine the depth of tumour invasion. Prior to clamping the renal artery, 12.5 g of mannitol and 20 mg of furosemide are given intravenously to induce diuresis. One or two bulldog clamps are placed on the artery beginning warm ischaemia time. The tumour is excised with cold scissors, and cautery is avoided to prevent charring of the normal renal parenchyma and preserve visualization. Once the tumour is freed, it is placed in an endoscopic entrapment sac for later removal. The renal defect is reconstructed by first closing the collecting system, if it is entered, with 4-0 absorbable braided sutures. Individual vessels are oversewn with 4-0 sutures. The base of the defect is oversewn 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. Once the defect is closed, the bulldog clamps are removed ending warm ischaemia time. The renal closure is observed, and additional 2-0 absorbable sutures are placed and secured with sliding locking clips if needed. A drain is placed, and the renal mass is removed.

3.3.2 Zero Ischaemia

This technique described by Gill et al. in 2011 requires a controlled hypotension during the anaesthesia [2]. The mean arterial pressure (MAP) is maintained at approximately 60 mmHg to ensure adequate oxygenation and perfusion of vital organs and tissues. Specifically, nadir hypotension is induced only during excision of the deep part of the tumour. Upon completion of tumour excision, blood pressure is restored to preoperative levels. Briefly, the hilar vessels are prepared and clamped en bloc using the Satinsky clamp or bulldogs. In cases with a medially located hilar or polar tumour, wherein the tumour or the tumour-bearing segment of the kidney is specifically supplied by a dedicated tertiary or quaternary renal arterial branch, meticulous microdissection and clip ligation of this specific vascular branch is done. Laparoscopic ultrasound is performed to identify the tumour and score its proposed resection margin. Tumour excision is begun with J-hook electrocautery through the full-thickness renal cortex to reach the medulla and sinus fat. MAP is incrementally reduced specifically during excision of the deep part of the tumour, commensurate with the amount of bleeding in the individual case. Then, the major intra-renal vessels in the renal sinus fat are identified, individually clip ligated with Hem-o-lok clips, and transected with cold scissors. Tumour excision is completed with cold scissors, followed by an initial layer of haemostatic sutures in the partial nephrectomy bed. MAP is gradually returned to baseline, and any residual bleeding vessels are suture ligated; thus, parenchymal reconstruction is always completed under normotensive conditions to assure complete haemostasis. Biologic haemostatic agents and Surgicel (Ethicon Inc, Somerville, NJ, USA) are applied to the resection bed, and the procedure is terminated.

3.4 Peri-operative Outcomes

Since its introduction in 2004 by Gettman and colleagues, RAPN has been steadily gaining acceptance as a viable alternative to both open and laparoscopic partial nephrectomy for patients with small renal masses suitable for nephron-sparing surgery (NSS) [3]. Initial series demonstrated that RAPN is a safe, minimally invasive procedure requiring a short learning curve to reach satisfying results in terms of peri-operative outcomes. In details, looking at the most relevant single series published between 2004 and 2010, the mean operative time was 194 min, the mean blood loss was less than 200 ml and the mean warm ischaemia time (WIT) was 25 min. Previous data were confirmed by the results of the first international multicenter study published by Benway et al. in 2010. In this study, the authors analysed 183 cases reporting a mean WIT of 24 min, a mean console time of 141 min, a mean blood loss inferior to 150 ml and an overall complication rate of 9.8 % (8.2 % major and 1.6 % minor complications) [4]. However, similar to other robotic procedures, >30–40 cases are needed to master RAPN, and it is expected that further improvement of the results will be parallel to the further progression in surgical experience. In our initial experience, the WIT <30 min was reached after the first 20 cases and a WIT <20 min after the first 30 procedures. Moreover, our study demonstrated a significant decrease in the WIT, console time and percentage of pericaliceal repair according to the increase of the surgical experience. In this single-centre series influenced by the learning curve, we observed only 2 (3.2 %) grade 3 complications according to Clavien classification. In both cases, patients had

postoperative bleeding due to arteriovenous fistula requiring selective percutaneous embolization [5].

Currently, in our experience, the operative time ranges between 80 and 120 min, the mean WIT using the early unclamping technique is 9 min (range 5–15 min) and estimated blood loss between 100 and 150 ml. The percentage of peri-operative complications decreased to 3.5 % in low risk cases and 15 % in more complex cases. No positive surgical margins were observed after the first 62 patients analysed to evaluate the learning curve period.

In 2011 Gill et al. proposed an anatomic targeted dissection and super selective control of tumour-specific renal arterial branches to facilitate the zero-ischaemia PN avoiding hilar clamping even for challenging medial and hilar tumours [2]. The conclusive message was that global surgical renal ischaemia appears unnecessary for the majority of cases suitable for RAPN, regardless of size or location of the tumour.

Currently, we prefer to use early unclamping technique, and when it is possible, a selective clamping of secondary arterial branches. In our opinion, the application of zero ischaemia should be reconsidered with caution. This approach is still complex (more than 4 h were required) also in the hands of very expert laparoscopic surgeons. Moreover, only preliminary data coming from a limited number of cases were available in literature. Therefore, preliminary results must be reconfirmed in prospective, single or multicenter, case series studies including a large number of patients and then further compared to the gold standard technique in the context of randomized or non-randomized studies.

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. Specifically, in a recent multicenter, international study of ours, we reported in patients with intermediate or high-risk tumours according to PADUA score a median WIT and console time of 20 and 120 min, respectively. Moreover, the percentages of intra-operative and postoperative complications were 4 and 17 % in the intermediate group and 6 and 15 % in the high-risk ones, respectively. Interestingly, in this multicenter experience, the authors reported grade 1 postoperative complications according to Clavien system in 10 cases (2.9 %), grade 2 in 21 (6.1 %), grade 3 in 7 (2.0 %), and grade 4 in 3 (0.9 %) [6].

Few data are available about the application of the RAPN in the treatment of cT1b tumours. In 2009 for the first time, Patel et al. showed the feasibility of the RAPN in a single-centre series including 15 renal tumours larger than 4 cm. In that study, RPN for tumours >4 cm showed comparable outcomes to RPN for smaller tumours, although with longer warm ischaemia times (25 min versus 20 min). Interestingly, in this preliminary experience, the authors reported an overall complication rate of 26 % with three major complications (19.8 %). Conversely, neither intra-operative complications nor positive surgical margins were reported [7]. More recently Gupta et al. published the results of a single-centre series analysing 19 procedures performed in 17 patients. In this series, the median WIT was 36 min, and the median blood loss 500 ml. However, no patient received blood transfusion during the peri-operative period, and the unique complication reported was a case of urine leakage and ureteropelvic junction obstruction requiring a postoperative stenting. However, three procedures required conversion to OPN due to excessive bleeding. No positive surgical margins were reported. Both previous studies did not show any significant impairment of the kidney functional comparing preoperative and postoperative (3 and 12 months) creatinine and eGFR values [8]. Only anecdotic data were reported about the feasibility of RAPN in selected T2 cases.

No study compared RAPN to OPN, and only few studies compared RAPN to LPN showing 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 [9].

3.5 Functional and Oncologic Outcomes

Available functional outcomes indicated excellent preservation of renal functional reserve 3 or 6 month after RAPN. However, the majority of these studies are based on the evaluation of creatinine levels (mg/dl) and/or estimated glomerular filtration rate (GFR) values [4, 5]. Therefore, the real impact of the surgery on the renal function could be masked by the normal contralateral kidney. No study evaluated the renal function of the treated kidney after RAPN using the renal scintigraphy. Studies evaluating the factors influencing the renal function after RAPN should be performed.

Considering the short follow-up reported in the majority of available series, only early oncologic outcomes can be evaluated after RAPN. Specifically, the risk of positive surgical margins ranges between 2 and 4 % of the cases in the most recent and wide series reported in Literature. This preliminary result can be considered overlapping with the percentages previously reported after open or traditional laparoscopic partial nephrectomy. Data concerning recurrence-free or cancer-specific survival after RAPN are still immature. Therefore, longer follow-up is mandatory also to confirm the oncologic effectiveness of this procedure at an intermediate and long-term follow-up.

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