# 2 Robotic Kidney Surgery

Jorn H. Witt and Christian Wagner

## 2.1 Introduction

Over the last 15 years, laparoscopic procedures in urology have become a widely used approach for many surgical indications [9]. In many specialized centers, laparoscopy is an integral part of daily practice [68]. The well-known difficult learning curve in laparoscopic procedures has lead to the developments of alternatives that shorten the learning curve and improve surgical outcomes. In kidney surgery, the popularity of hand-assisted nephrectomy, especially in the USA, is a good example for a pragmatic approach to improve the learning process [31]. Since the introduction of telemanipulatory devices in the beginning of the last decade, robot-assisted procedures for many indications have become the preferred approach of many urologists. Notably, in complex reconstructive and advanced ablative surgical procedures, the robot offers advances to the surgeon providing 3D vision and seven degrees of freedom of motion in the hand-wristed instruments, scaling of motion, and reducing of tremor [48].

The proven benefits for laparoscopic kidney surgery, compared with open procedures, such as less pain, shorter hospital stay, and faster return to normal activity and favorable cosmetic results, could be also demonstrated for robotic renal surgery [40, 42, 47].

This chapter describes current ablative and reconstructive robotic procedures, considerations for the choice of different approaches, and the management of possible complications.

## 2.2 Patient Evaluation and Preparation

Evaluation and preparation for robotic kidney procedures follow the same principles as comparable standard laparoscopic or open surgery [4, 9, 12]. Prior to surgery, possible complications including injuries of the bowel, vascular structures, nerves, spleen, pancreas, liver, diaphragm, and collecting system (in nephron-sparing cases) must be discussed with the patients; also conversion to open surgery in consequence of surgical or technical reasons should also be specified [34, 76] to obtain informed consent. Furthermore, OR technicians/nurses should be always prepared for conversion.

There are no robot-specific contraindications in renal surgery, but, for example, multiple prior abdominal surgeries or status post-peritonitis may influence the choice of a transperitoneal robotic approach, particularly for beginners. Obese patients in general have a lower risk of postoperative wound infection or pulmonary complications in laparoscopic procedures; however, the identification of anatomical structures could be more delicate; working space may be reduced, so the possibility for conversion to open surgery is higher in obese patients [88].

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General laboratory and imaging studies depend on patient history and indication. Bowel preparation is usually not mandatory but could be considered subject to the approach, prior peritoneal surgery and the preference of the surgeon. In dilated bowel loops, the presumption of adhesions and anticipated complex procedures, we consider bowel preparation with purgative the day before surgery [68].

Depending on the disease and the procedure, special imaging and examination includes ultrasound, i.v. pyelogram, CT or MRI scan, and dynamic renal scan. Stenting of the ureter prior to the procedure can be helpful in selected cases.

## 2.3 General Considerations for Robotic Kidney Surgery

In addition to open and standard laparoscopic procedures, two main aspects should be focused in robotic kidney surgery: (1) robot installation and (2) selection of the robotic instruments [54].

The patient cart is usually placed on the side of the patient's back, mainly with the camera arm at the level of the targeted lesion. Right-angle positioning of the robot to the patient's back is used in most cases [58]. Since newer versions of the robot are available that offer more flexibility of the robotic arms, also oblique positioning of the arms is possible and could be helpful in selected cases.

A possible OR setting is shown in Fig. 2.1.

Robotic procedures can mostly be performed with a limited number of instruments. For most procedures, three or four robotic instruments are adequate. Table 2.1 indicates a list of instruments used in our institution and possible alternatives. For suturing, one or two needle drivers can be used due to the preference of the surgeon. Since one additional instrument adds some 250–300€/US$ to the procedure, well-considered instrument selection is economically worthwhile.

Typical useful instruments are listed in Table 2.1.

## 2.4 Surgical Approaches

As in standard laparoscopy, both transperitoneal and retroperitoneal approaches are possible for robotic kidney surgery. Randomized trials have shown no significant differences in standard laparoscopy between transperitoneal and retroperitoneal access regarding operative time, results, and complications, but did report a significant faster resumption of oral intake for the transperitoneal group [68]. The transperitoneal approach allows an optimal working space and more possibilities for different trocar placement. The orientation by anatomical landmarks is also easier in the transperitoneal approach [45]; thus the transperitoneal approach should be considered easier for beginners.

Retroperitoneal access requires an adequate working space in the retroperitoneum before trocar placement; this can be either achieved by special dilating balloons or blunt dissection with the surgeon's finger. Identification of anatomical structures may be unfamiliar especially for surgeons who are not accustomed to this approach. For patients with a history of peritonitis, multiple prior abdominal surgery, and abnormalities of the posterior surface of the kidney, the retroperitoneal access could be superior to the traditional transperitoneal approach [15].

There are some reports of hand-assisted approaches combined with robotic surgery [70]. Due to handling advantages in robot technology, procedures are easier also for less experienced surgeons so that possible benefits of the hand-assisted technique are without doubt less important than in standard laparoscopy [49].

### 2.4.1 Transperitoneal Approach

#### 2.4.1.1 Patient Positioning and Port Placement

In all laparoscopic procedures, patient positioning and port placement are major condition requirements for a trouble-free target approach and a successful accomplishment of the procedure. In robot-assisted techniques, additionally the adequate distance between robotic arms for unrestricted movements and optimal placement of the robot beside the patient is essential for straightforward docking [45, 82].

The patient is placed in a modified lateral decubitus position with a 20–30° ipsilateral rotation of shoulder and hip. For most cases, the

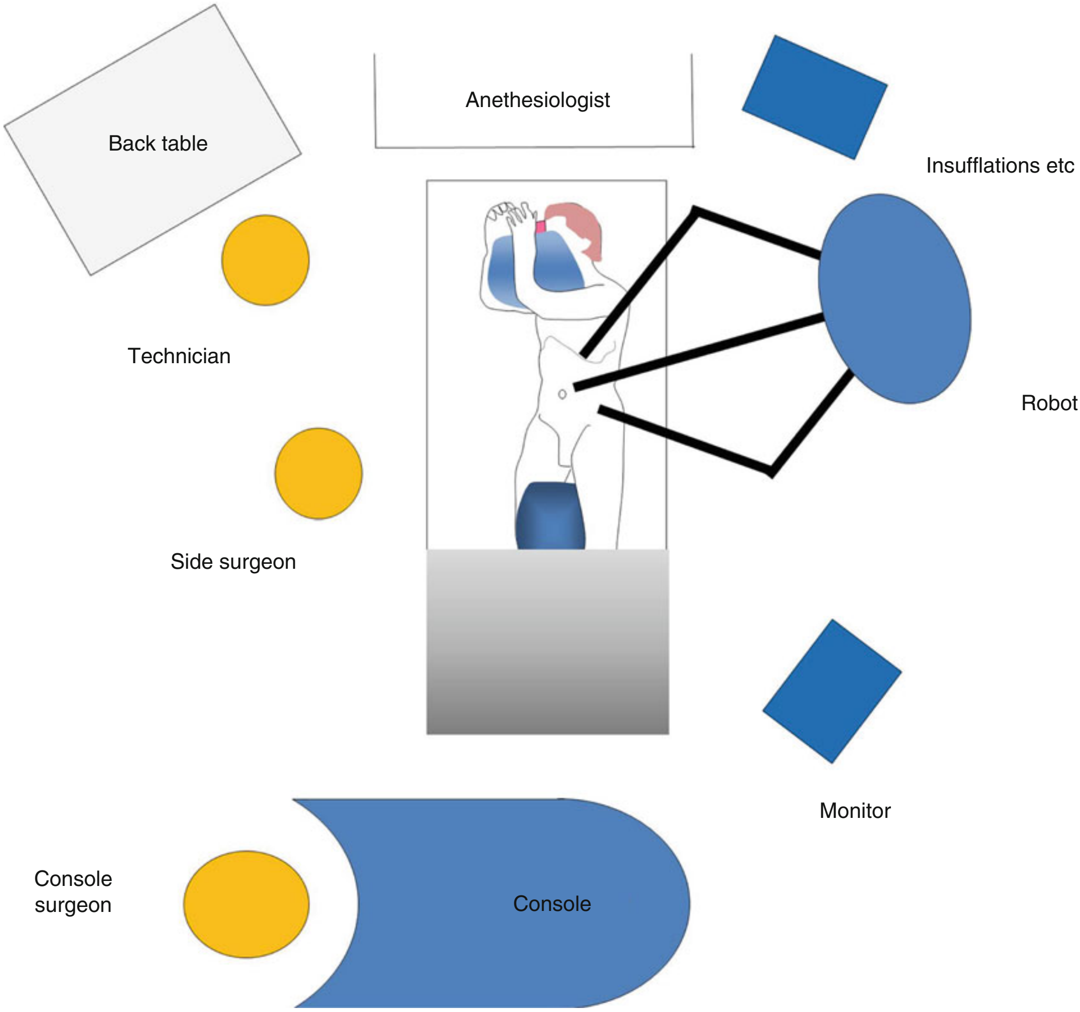


**Fig. 2.1** OR setup

ipsilateral arm can also be placed close to the patient side. If desired bending of the operating table can be performed at the level of the umbilicus before securing the patient at the table, for example, with adhesive tape. We prefer a vacuum bedding device as an inexpensive, reusable, and safe tool for proper patient positioning on the table. After securing on the table, the patient can easily be rotated to the full flank position. The complete ipsilateral flank is prepared and draped, and a Foley catheter is placed in the bladder before trocar placement.

Figure 2.2 illustrates port positions; for initial insufflation, we prefer the open Hasson technique with minilaparotomy. Alternatively, a Verres needle can be used. There are generally two major approaches for transperitoneal kidney surgery: the medial and the lateral camera port placement. In the medial camera placement, the camera port is placed pararectal at the level of the umbilicus. The two robotic arms are placed in the midclavicular line in triangular fashion with the camera port. A minimum distance of 8 cm between the ports is necessary to avoid collision of the robotic arms during the procedure. The assistant port is placed pararectally between umbilicus and pubic bone. If needed, additional assistant ports can be placed below the xiphoid (often helpful for liver retraction in right-side kidney surgery) and below the costal arch if possible [81]. For medial camera port placement,

**Table 2.1** EndoWrist™ Instruments for robotic renal surgery

| Instrument | Alternative instrument(s) | Use | Suggested arm (sinistrals may switch position) |
|---|---|---|---|
| *Typical instruments* | | | |
| Monopolar curved scissors | Permanent cautery hook | Cutting, preparation and monopolar cautery in most procedures | Right |
| | Curved scissors | | |
| | Round tip scissors | | |
| Large needle driver | SutureCut needle driver | Suturing (two or in combination with Maryland/PK dissector) | Right or both |
| PK dissector | Fenestrated Maryland bipolar | Preparation, dissection, grasping, bipolar cautery, and suturing | Left |
| | Precise bipolar | | |
| Harmonic curved shears | Ultrasonic shears | Kidney/pelvic preparation | Right or left |
| *Instruments for special situations* | | | |
| ProGrasp forceps | Cadiere forceps | Holding/elevating | Left |
| Potts scissors | | Ureter incision | Right |
| DeBakey forceps | | Grasping of delicate structures, suturing | Left |

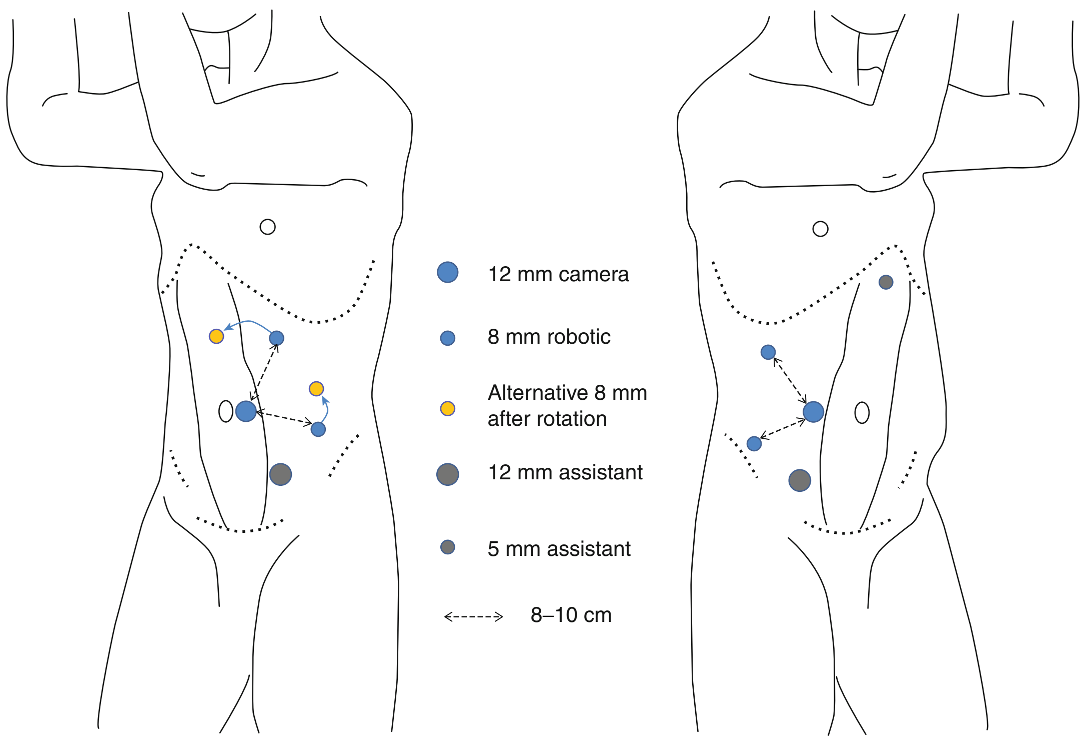


**Fig. 2.2** Port placement for transperitoneal procedures. In obese patients (*right*), trocars should be shifted laterally. An additional port inferior to the xiphoid for liver retraction is often helpful

usually a 0° or a 30° down lens is used. One possible disadvantage of this approach is the limited space for the assistant, because camera arm and the robotic arms reach very far into the direction of the assistant. Also, this could lead to quite dangerous collisions with additional instruments, such as a laparoscopic Satinsky clamp, that are attached to delicate structures like the renal hilum. The advantage is a broader view over the operative field, which makes orientation easier.

For lateral camera port placement, the port is placed lateral to the midclavicular line [3]; therefore, a 30° up lens is useful. The possible disadvantage of this approach is a very close view of the operative field which could lead to a lack of overview plus slightly reduced space inside the abdominal cavity for camera movements; the table-side assistant has an easier access to his ports, which can be beneficial.

Port placement for robotic laparoscopic procedures of the kidney is less straightforward than pelvic procedures [45]. The best placement of ports depends on many variables. Especially for upper pole kidney surgery, the whole setup should be shifted upward and can be rotated. In obese patients, trocars should be placed more laterally [33, 44].

Considerations, such as location of interest (upper pole, lower pole, and hilum), interference of dissection because of large organ or tumor size, distorted renal anatomy, and the individual patient's physical features, affect the optimized port positioning. Preoperative imaging is obligatory in the proper planning of the surgical approach.

#### 2.4.1.2 Left-Side Kidney Preparation

Using a PK dissector and monopolar scissors, dissection is started by incising the white line of Toldt lateral to left colon and bringing down the descending colon. Alternatively, a cautery hook or ultrasonic energy ("harmonic scalpel") could be used instead of the scissors. The mobilization of the colon should be at the same level throughout its length; cranially, the kidney should be made free to the level of the spleen, and caudally, the colon should be mobilized to the level of iliac vessels. In case of nephroureterectomy, the sigma also has to be mobilized to follow the ureter in the pelvis. Medial traction by the assistant helps clearing of anterior Gerota's fascia by identifying additional colorenal attachments. The lienocolic and phrenicocolic ligaments are incised to allow the left colic flexure to fall medially along with the pancreas. Care has to be taken to leave the kidney attached laterally to avoid a flipping into the operative field which could make hilar dissection difficult.

The psoas muscle is identified and followed medially to expose gonadal vessels and ureter. The gonadal vessels which are usually first encountered should be swept laterally to expose the ureter. Both structures are then followed proximally to the lower pole of the kidney. Our group also prefers in ablative procedures not to divide the ureter at this point because lateral traction on ureter and lower kidney pole can help to identify the renal hilum. The gonadal vein can be traced proximally to the renal vein.

#### 2.4.1.3 Dissection and Securing of the Renal Hilum

Safe dissection of the renal hilum requires two conditions: (1) medial retraction of the colon and bowel by gravity or infrequently by an additional retractor and (2) lateral retraction of the kidney by lifting it out of the renal fossa. Lifting the kidney to the lateral abdominal wall will place tension on the vessels, helping identifying and controlling anticipated structures and accessory vessels. Anterior dissection is performed layer by layer with the PK dissector until the renal vein is uncovered. Gonadal, lumbar, and accessory venous branches can then be clipped and divided when identified. The inferior adrenal vein can be preserved when adrenalectomy is not required but has often to be clipped. The renal vein and artery can then be cleaned off carefully (Fig. 2.3). In most cases, the artery is best approached inferior to the vein, but access from superior is also appropriate if easier. Preoperative imaging can help identifying accessory pole arteries or an early division of the main renal artery into the major branches.

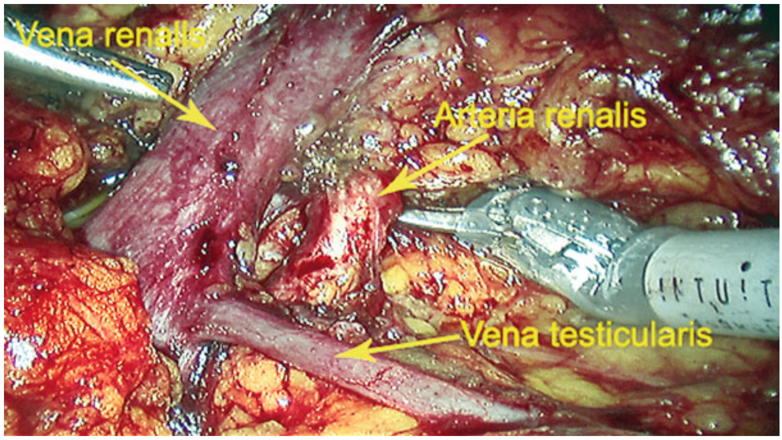


**Fig. 2.3** Renal hilum (left side)

In ablative surgery, the renal artery is usually divided first. Clips, stapler (endovascular gastrointestinal anastomosis = GIA staplers), or suturing can be used in robotic surgery [57]. Clipping and stapler firing has to be done by the table-side surgeon, also a robotic clip applier can be used, the downside is the additional costs for the instrument plus the lack of one robotic arm to keep the hilum under stretch while clipping. If desired suturing of the vessels, like in open nephrectomy, is possible due to the wrist-like movements of the robotic instruments. We prefer the use of at least two Hem-o-lok clips proximally and one distally. When using GIA staplers, care must be taken not to entrap clips from smaller vessels divided before [20].

For nephron-sparing procedures, a laparoscopic bulldog or Satinsky clamp is used on the artery and on the vein, either combined artery and vein or separated; alternatively, clamping the renal artery alone has been described as a useful approach in case of aberrant vascular supply to the kidney. A vascular tourniquet with a cut drainage tube is also a safe and feasible manner to achieve a nearly bloodless field.

#### 2.4.1.4 Right-Side Kidney Preparation

Access to the right renal hilum is more unpretentious than on the left side due to the fact that the right kidney is an organ with more contact to the peritoneum. In left flank position, the ascending colon and the right colic flexure drop down usually exposing anterior surface of the kidney. Analogous to left-side preparation, the line of Toldt is incised from coecum to colic flexure, and gonadal vein and ureter are identified at the pelvic brim. The right gonadal vein is followed proximally to the inferior vena cava and secured and divided, if desired. By tracing the vena cava, the duodenum is released, and the renal vein is located. The steps in dissecting and securing of the renal vessels are similar to those previously described for the left side.

### 2.4.2 Retroperitoneal Approach

#### 2.4.2.1 Patient Positioning and Port Placement

Retroperitoneoscopic robotic renal surgery affords, similar to open surgery, a complete, bended flank position. Available space and possible positions for port placement are nevertheless restricted compared to transperitoneal approaches. A slightly anterior rotation of the operation table allows the peritoneum and its content to drop away ventrally resulting in some more working space in the retroperitoneum. Two different possibilities for retroperitoneoscopic port placements are shown in Fig. 2.4. The robot is docked again from the patient's back. For better right arm docking, the robot should be installed in a 45° position to the operation table when the camera port is placed over the iliac crest.

The first step is to create the retroperitoneal working space. A 12-mm incision is made off the tip of the twelfth rib, and the surgeon's index finger is used to penetrate bluntly through the muscular layers into the retroperitoneal space. By

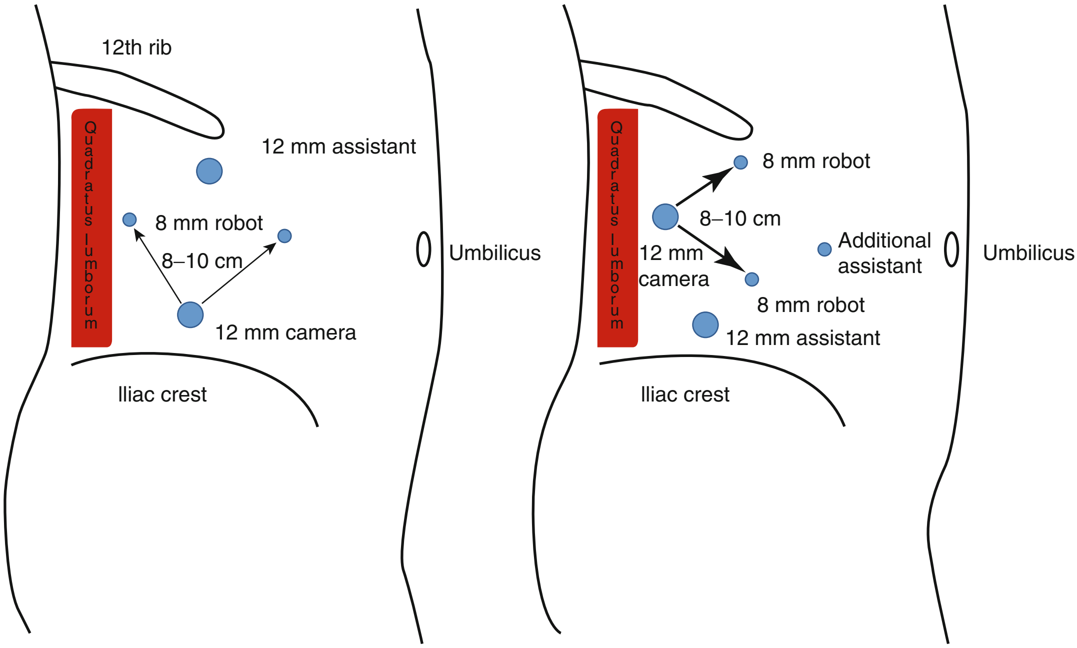


**Fig. 2.4** Retroperitoneal port placement

entering the correct space, the surgeon should feel the lower pole of the kidney downward, the tip of the 12th rib upward and the smooth surface of the psoas muscle. Then the retroperitoneal space is created by using the middle finger of an 8½ glove mounted on a trocar or a catheter which is filled with 700–800 ml saline. Alternatively, commercial distension balloons are available [28, 66]; some surgeons prefer create the space with the optical camera itself.

Under direct vision, 8-mm robotic trocars and a 12-mm camera trocar are placed using blunt tips. Again an 8- to 10-cm right-angle setting of the robot trocars is required to allow for adequate robot arm movements and to avoid arm collision. Working space could then be extended if necessary. The initial incision is used as the assistant port for the table-side surgeon. In case of alternative port placement, the initial incision has to be reduced by suturing for the 8-mm robot port; hybrid technique (inserting the robot port through established 12-mm port) is also possible [82].

#### 2.4.2.2 Kidney Preparation

The orientation in the fatty tissue may be more difficult, especially in obese patients, due to unavailable typical anatomical landmarks in the beginning of the procedure. First the psoas muscle should be identified; by dissecting medially, the ureter and the gonadal vein are encountered, a penetration of the overlying peritoneum has to be avoided. Then the dissection of the renal hilum follows the same principles as in the transperitoneal approach. Tension on the ureter and lower kidney pole helps to identify vascular structures. The surgeon must be aware of the different direction of preparation compared to the transabdominal approach. Aorta or vena cava inferior is located perpendicular below the ureter with the risk of accidental injuries. Access to the renal artery is usually more direct than in transperitoneal surgery. On the right side, camera orientation should be rechecked before clamping or securing the assumed renal vein due to reports of ividing the vena cava during standard laparoscopic nephrectomy [65].

## 2.5 Nephrectomy

### 2.5.1 Simple Nephrectomy

Robotic simple nephrectomy can be used for almost all benign renal diseases that require kidney removal. Chronic pyelonephritis, obstructive or reflux nephropathy, nephrosclerosis, and renovascular hypertension can be treated as well as symptomatic acquired renal cyst disease or symptomatic autosomal dominant polycystic kidney disease [41, 55]. Depending on the primary disease and the duration of patient's history inflammatory adhesions between the kidney and surrounding tissue and fibrosis of perirenal tissue "simple" nephrectomy may be a very delicate procedure.

Kidney preparation is described in Sect. 4.1.2 and dissection and securing of renal artery and vein in Sect. 4.1.3.

On the left side, the inferior adrenal vein can often be preserved. After controlling of renal vessels, the preparation is continued circumferentially at the upper pole by peeling of the Gerota's fascia from the kidney. The use of ultrasonic energy (ultrasonic shears or harmonic curved shears) on the left robotic arm facilitates the preparation of the upper pole and the lateral and dorsal aspect of the organ by simultaneously coagulating small vessels. The use of a LigaSure device by the table-side surgeon is also possible but requires a good cooperation between console and table-side surgeon. Preparation and dissection by bipolar PK dissector and monopolar hook or scissors (Hot Shears™) is also possible but is often more time-consuming.

At the end of the procedure, the ureter is divided after clipping at the level of the iliac vessels, or as far distally as possible. The specimen is entrapped in an endocatch bag and removed after undocking of the robot. This could be done by extending the camera trocar site at the level of the umbilicus or alternatively by widening the robot or assistant trocar site in the lower abdomen. Some surgeons prefer morcellating of the kidney inside the retrieval bag [9, 93].

A drain can be placed in the renal bed at the end of the operation if necessary or due to preferences of the surgeon.

### 2.5.2 Donor Nephrectomy

Donor nephrectomy follows the same principles as described for simple nephrectomy regarding some special aspects and modifying the surgical steps. Due to the length of the renal vein, the procedure is usually performed on the left side.

At the beginning, a 7-cm midline incision is made below the umbilicus. After opening the abdominal cavity, a hand-port device is inserted, and pneumoperitoneum is established [13]. After robot trocar placement (camera port pararectal, 8-mm robot arm ports midline between xiphoid and umbilicus and left lower abdomen), a 12-mm assistant port is placed in the lower abdomen or below the xiphoid [48].

Before dividing renal vessels, the kidney has to be completely mobilized and the ureter traced below the level of the iliac artery. Care has to be taken not to compromise the ureteral blood supply by leaving a sufficient amount of periurethral tissue on the ureter. After dissecting of the renal vein and dividing its tributaries (adrenal, gonadal, and if present lumbar veins) by LigaSure device or clipping, the artery (or arteries) are followed to its aortic takeoff.

Then the ureter is clipped and divided. At this time, most groups administer heparin [50]. Then artery and vein are divided by GIA stapler; the use of Hem-o-lok clips in case of living donor nephrectomy is not approved. The kidney is removed immediately through the hand port, on the back table staples are removed from the vessels, and the kidney is flushed with preservation solution [51, 78].

After inspection of the renal bed to ensure hemostasis, the robot is undocked, trocars are removed, and wounds are closed, with or without leaving a drain.

### 2.5.3 Radical Nephrectomy

Laparoscopic radical nephrectomy has become an established and widely used procedure by many experienced centers [38]. In the 2010 EAU Guidelines on renal cell carcinoma, it is considered as the standard of care in patients with $T_2$ tumors or $T_1$ tumors in which partial nephrectomy is not indicated. Outcome data indicate equivalent cancer-free survival rates when compared with open radical nephrectomy by reduced morbidity and less inflammatory and immunologic reaction of the organism after surgery [16, 21].

The laparoscopic approach duplicates the oncological principles from open surgery [37]. In addition, port site seeding must be avoided by using following precautions: minimizing direct tumor handling, en bloc resection of the tumor including surrounding tissue, entrapping all tissue in impermeable retrieval bag before removing, redraping of port sites at time of specimen removal, avoiding of positive margins, and change of gloves for all table site staff before wound closing [18, 30].

Robot technology allows for all described steps of laparoscopic radical nephrectomy with the additional virtue of better dexterity of the instruments and 3D vision.

Preoperative evaluation is the same as in open surgery including imaging of the tumor size, possible extension in perirenal structures, and status of the vein for possible tumor thrombus and exclusion of presentable metastasis.

Patient positioning, port placement, preparation of the kidney, and dissection of the renal hilum are described in previous chapters depending on trans- or retroperitoneal approach and side of surgery.

Before dividing the vein, it should be carefully inspected if there is any question of tumor thrombus. The dissection is then performed external to Gerota's fascia at all times. Simultaneous adrenalectomy is performed in upper pole tumors or large mass tumors. After dividing the inferior adrenal vein, the preparation is followed cephalad medial to the adrenal, and additional veins and artery supply are identified and clipped. On the left side, the tail of the pancreas should be gently pushed medially. On the right side, an additional 5-mm port for liver retraction is often necessary.

After the nephrectomy, lymphadenectomy is performed. Lymphadenectomy should be restricted to the perihilar tissue for staging purposes since extended lymphadenectomy has been shown not to improve survival. Lymphatic tissue is dissected by clips, bipolar coagulation, or ultrasonic energy. Care has to be taken of lumbar veins on the right side and of lumbar arteries on the left side to avoid bleeding complications which may be difficult to handle laparoscopically. Although lymphadenectomy is usually a limited staging procedure in renal cancer, extended robotic retroperitoneal lymphadenectomy is possible nearly without limitation [1, 26, 90].

We always remove the intact kidney by expanding the camera port incision (alternatively the assistant port in the lower abdomen). Morcellating procedures are also described [59, 60], but histopathologic examination can only lead to reliable results with an intact specimen.

## 2.6 Nephron-Sparing Procedures

Nephron-sparing or partial nephrectomy has become a widely used technique in tumors smaller than 4 cm or in patients with solitary kidney, suboptimal kidney function, or bilateral tumors [10, 41, 61, 86]. The largest obstacle to the widespread use of laparoscopic partial nephrectomy is its technical difficulty. Limitation of instrument dexterity makes tumor excision, hemostasis, and reconstruction of the collecting system a quite challenging procedure even for experienced laparoscopic surgeons. Warm ischemia of the kidney is restricted to approximately 30 min due to potential loss of renal function, so the procedure has to be performed in a quick and safe manner [79, 80].

The same considerations that changed the view of both surgeons and patients about radical prostatectomy over the last years are obvious in nephron-sparing surgery. Advanced instrument movements and excellent visualization facilitate the surgeon to accomplish especially the delicate steps of this procedure [17, 35, 72].

Patient evaluation, preparation, and positioning are described before. In selected cases with the expectation of an extensive repair of the collecting system, stenting of the ureter prior to surgery may be considered, but is usually not necessary. Renal outside or inside cooling is usually not necessary but could be useful in special situations (e.g., large tumor in solitary kidney, central tumors).

After identifying of the ureter and aorta/vena cava, isolation of the renal vessels and mobilization of the kidney is performed as described before. We use PK dissector, monopolar curved scissors, and needle driver for the whole procedure. The tumor is localized, and renal capsule is exposed, leaving perirenal fat on the specimen (Fig. 2.5). Intraoperative use of a laparoscopic ultrasound probe by the table-side surgeon may help identifying the tumor and defining the line of resection [79, 80] and the vascular supply of the tumor. The TilePro tool of newer robotic generation allows for a picture-in-picture technique (Fig. 2.6).

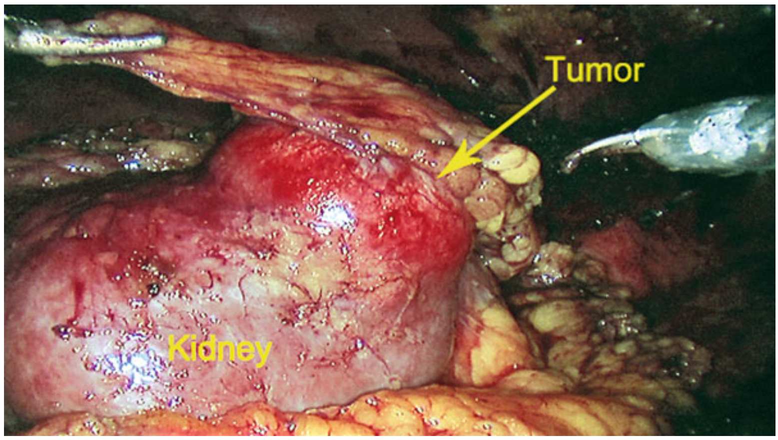


**Fig. 2.5** Tumor after preparation. The perirenal fat is left on the tumor

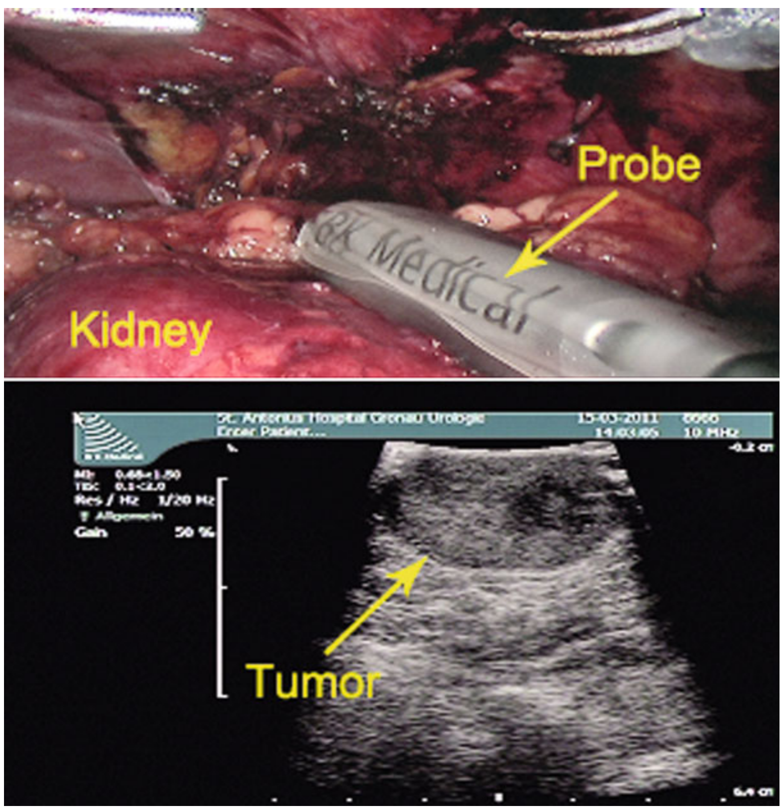


**Fig. 2.6** Console view with ultrasound probe on the tumor (*above*) and ultrasound picture (*below*)

Before clamping of the renal vessels, the line of incision is superficially marked with the Hot Shears on the renal capsule. About 20 min prior to clamping, 12.5 g mannitol is administered by the anesthesiologist [72, 87].

The table-side surgeon is clamping the renal artery (and vein on right-side procedures or large tumors) with laparoscopic bulldog clamps after elevating the kidney by the console surgeon to expose and stretch the hilum [91, 94]. The use of a Satinsky clamp is also described but not our preference [72]. The "tourniquet technique" by using a vessel loop around the artery (or vein) and suspending the blood flow by traction on 3-cm 18 F drain through which the loops are guided is a good alternative (Fig. 2.7).

After marking (Fig. 2.8) and incision of the capsule, the tumor is excised using the scissors without electrocautery. The PK dissector is used for traction and exposing and coagulation of perforating arteries. Larger arteries should be clipped (Fig. 2.9). The use of ultrasound energy for coagulation is also described [98]. The suction device of the table surgeon helps by keeping the field clear of blood and exposing structures by countertraction. If a positive margin is suspected, a new, deeper plain of excision is created. Verifying the line of dissection by ultrasound probe may be helpful [53]. The excised specimen is placed beside the kidney. Biopsies for frozen section can be collected from the base of the lesion with the robotic scissors or a sharp grasper handled by the side surgeon.

The base of the lesion is checked for large perforating vessels and defects of the collecting system. After replacing the scissors by a needle driver (due to surgeon preferences two needle drivers could be used), suturing of vessels and, if necessary, defects

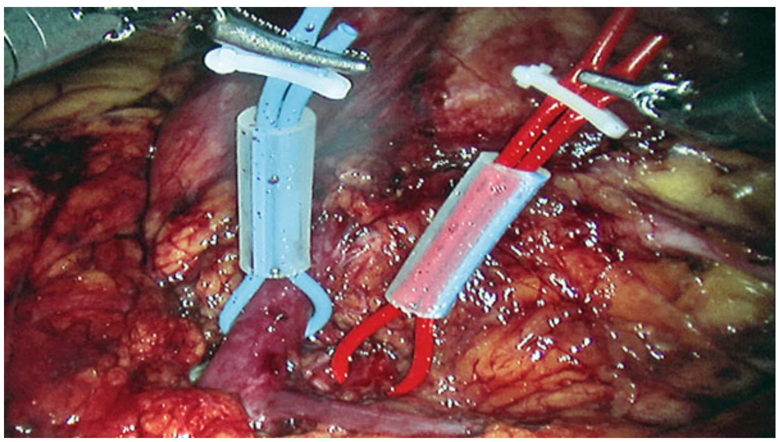

**Fig. 2.7** Situs prior to clamping, loops around vein (*blue*) and artery (*red*). In most cases, clamping of the artery is not necessary

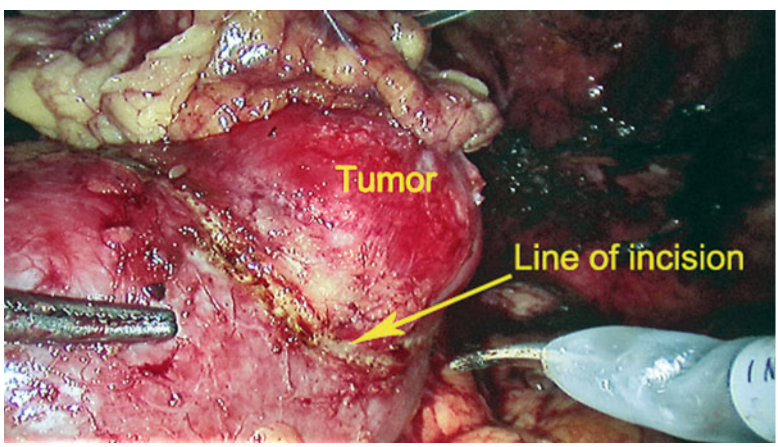


**Fig. 2.8** The line of excision is marked with electrocautery

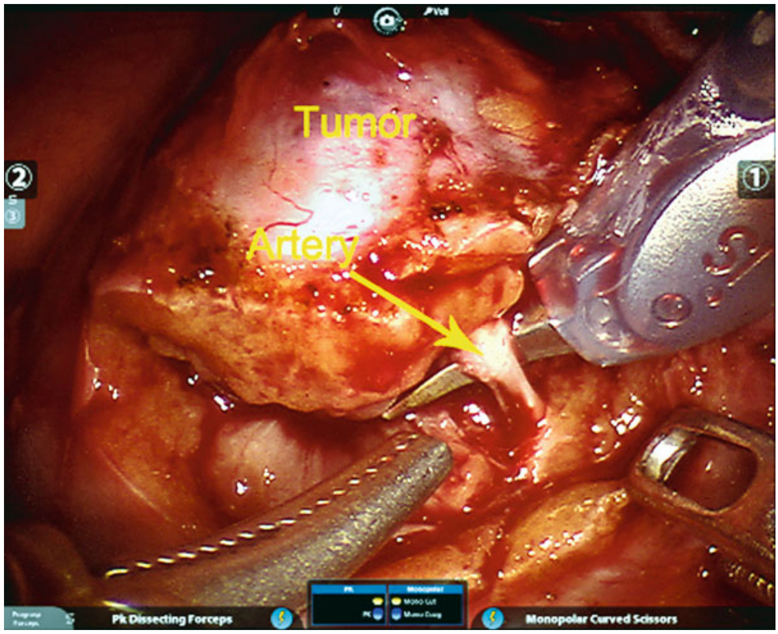


**Fig. 2.9** Clipping of a larger artery during excision of the tumor

in the collecting system is performed with a 3/0 absorbable monofilic or braided suture (e.g. polyglyconate) on a small needle (e.g. RB-1 or HR 17). Also the use of a barbed suture (V-Loc™) for the deep layers is now common alternative. Additional hemostasis of the parenchyma can be achieved with an argon beam (one must be aware of the possibility of rapid increasing intraabdominal pressure caused by cautery gas) [74, 85]. Argon beam coagulation and other described additional forms of hemostasis (e.g., FlowSeal™ or TissueLink™) [73, 74, 95] are usually not necessary for adequate hemostasis in our hands. Bolstering of the defect is in most cases not necessary; in large defects, where sufficient approximation of excision rims cannot be achieved otherwise, bolsters can be helpful.

The defect is closed by renorrhaphy, utilizing a running suture on a large needle and using a sliding clip technique (Fig. 2.10); also a barbed suture can be used.

After elevating the kidney by the console surgeon, the bulldog clamps are released and retrieved. Early unclamping (after the first layer of suturing) reduces warm ischemia time and should be performed whenever possible. Hemostasis is confirmed, and perirenal fat is sutured over the defect in running technique. The tumor is placed in an endocatch bag for removing at the end of the surgery. Lateral fixation of the kidney is only performed in cases with extended kidney mobilization. We prefer to place a drain beside the defect or the hilum; in straightforward procedures or exophytic tumors, drainage could be renounced; in case of an obviously open collecting system, a drain should be put to avoid urinoma. After undocking of the robot, the specimen is removed through the site of the optic trocar or the assistant trocar in the lower abdomen.

## 2.7 Nephroureterectomy

Indications for nephroureterectomy are upper urinary tract transitional cell carcinoma with the need of resection of a bladder cuff and hydronephrosis caused by distal ureteral obstruction without the necessity for bladder opening [9, 14].

The surgical steps for removing of the kidney are described in previously chapters. As with other robotic renal procedures, trans- and retroperitoneal approach is possible. We prefer the transperitoneal approach due to easier access of the distal ureter and bladder wall. Especially when using the standard da Vinci system, the camera port should not be placed above the level of the umbilicus to avoid problems accessing the pelvis and the ureteral orifice [69]. The robotic arms should be placed as far away from each

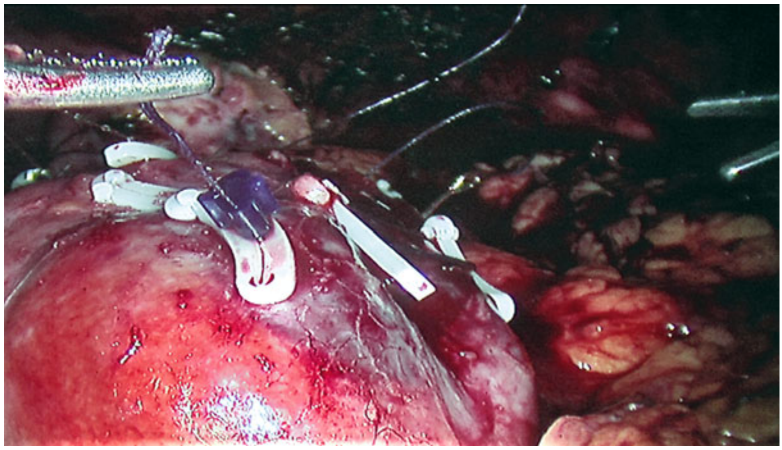

**Fig. 2.10** Renorrhaphy in sliding clip technique

other as possible; this allows for a wide range of motion between robotic arms and the camera arm; access to the distal ureter can be achieved. If difficulties are encountered, redocking of the robot with adjustment of the arms can facilitate surgery: The camera trocar can be left in place, but the patient cart is driven over the shoulder of the patient, the operating table is slightly turned, and the previous right robotic arm is now attached to the previous left trocar; the right robotic arm is attached via a hybrid port-in-port technique to the previous assistant trocar.

By following the ureter in the pelvis, the peritoneum has to be incised medially or laterally to the medial umbilical ligament, and the vas deferens in males or the round ligament in female patients is clipped or coagulated and divided as encountered. After clipping of the ureter distal to the tumor, the ureter is dissected to its passage through the bladder wall.

The bladder is irrigated with 100-ml saline, and the bladder cuff is excised with the monopolar scissors [39, 52, 63]. After replacing the scissors with the needle driver, the bladder wall is subsequently closed with a 2/0 Vicryl running suture on an SH needle. This part of the procedure is easy to perform with the robotic instruments on contrary to standard laparoscopic approach [69]. The specimen is removed by a semi-Pfannenstiel incision on the side of surgery, in women, extraction of the retrieval bag through the vagina can be performed. If gaining appropriate access to the bladder wall is difficult (or if preferred by the surgeon), the procedure can also be finished in standard open technique; also a previous or even simultaneous transurethral incision of the bladder cuff can be performed , which facilitates this last step of the surgery.

## 2.8 Other Procedures

The experience of our group in other robotic kidney surgery is limited, just as reports in the literature. One publication demonstrated the feasibility of management of partial staghorn calculi by extended pyelolithotomy [2, 43].

In principle, renal surgery procedures such as nephropexy, cyst decortication, calyceal diverticulectomy, and pyelolithotomy that have been publicized for standard laparoscopy approaches [5, 6, 23, 29, 46, 64, 92] should be possible in robotic kidney surgery with potential advantages due to the technology.

Besides the still relatively young technology, reasons for limited experience in infrequent kidney procedures at this time may be economical aspects and the limited operation room capacity. Many centers are working to full capacity by radical prostatectomies and have only restricted robot time slots for other procedures.

## 2.9 Postoperative Management

As in other laparoscopic procedures, early mobilization of the patient (on the day of surgery) is recommended. Oral intake beginning on the day of procedure and return to full oral intake on day one or two is possible if tolerated. Catheter could be usually removed on the day of surgery or day one with exception of nephroureterectomy (we check for leakage on day 5–7 by cystogram). Also a possible drain could be removed in most patients on day one [77, 96].

Many patients could be discharged on day one, and hospitalization is rarely longer than a few days.

## 2.10 Complications and Management

Even in the hands of most experienced surgeons, complications are an unavoidable consequence of surgical practice [9]. The patient has to understand that factors related to anatomical conditions or due to the disease, operating room environment, and technical problems could lead to such undesirable conditions. Efforts at prevention should be maximized. In case of complications, early recognition and appropriate management is necessary to avoid fatal consequences [32]. Fatal robot errors are rare; procedures can often completed by standard laparoscopy, and in difficult situations, conversion to open surgery may be considered [75].

Overall (minor and major) complication rates reported in the literature for (simple and radical) nephrectomy is between 6 and 17 % [9, 56]. Complications are possible during the whole procedure, either surgeon-related as well as due to the anesthesiologist [62, 97]. Typical surgical complications include bowel injuries, solid organ injuries (mainly liver, spleen, pancreas), bleeding problems at trocar site (epigastric vessels), intra- and retroperitoneal bleeding (hilum, adrenal, mesenterial, lumbar and gonadal vessels; vena cava; aorta), urine leakage, subcutaneous emphysema, trocar hernia, and trocar site infection [27, 84].

Bleeding complications from renal vein or artery could be life threatening, and in doubt rapid conversion to open surgery may be necessary [67]. In such situations robot undocking is technically possible in less than one minute and should be trained on a regular base. Literature reports indicate that bleeding complications due to stapler or clip malfunction occur occasionally; they are conditional on technical reasons and could be avoided by the following safety measures: keep tip of stapler or clip free of tissue, no stapling over clips, no traction on applied clips, and correct stapler position with complete transaction [20].

Injuries of the diaphragm and port hernias (mostly at the site of organ removal) are less frequent, port hernias can be avoided by wound closure in layers of ports larger than 8 mm of size; useful tools against for port site hernia are, for example, the Berci needle or the Carter Thomason CloseSure device. Other complications include prolonged intestinal hypomotility, (transient) skin numbness, testalgia, deep vein thrombosis/pulmonary embolism, and pneumonia [11, 22, 71, 89].

Intravascular volume overload during surgery by the anesthesiologist should be avoided due to the fact that the laparoscopic approach has far less insensible fluid loss compared to open surgery.

In case of postoperative oliguria and hemodynamic instability, bleeding should be excluded as the cause.

In contrast to recognized bowel injury during surgery which can be sutured and usually does not lead to problems, unrecognized or delayed bowel injury may be fatal for the patient. Common causes for bowel injuries are direct or indirect electrocautery (mind that metal instruments can conduct electric current outside the surgeon's view as well), Verres needle or trocar placement [9]. We recommend not using monopolar energy when working in close proximity to the bowel; also using the Hasson technique for the primary access and placing all trocars under direct vision as a rule – and if possible in blunt technique – is an effective means to prevent bowel injury.

Patients with bowel injuries after laparoscopic procedures are often less symptomatic than after open surgery [8]. Patients with unrecognized bowel injury after laparoscopy typically present with persistent and increased trocar site pain at the site closest to the bowel injury. Increasing inflammatory blood parameters and persistent bowel sounds could lead to diagnosis. Later, signs and symptoms include nausea, diarrhea, reduced general condition, low-grade fever, and a low or normal white blood cell count. The patient's condition can rapidly deteriorate to hemodynamic instability and death if the injury is not quickly recognized and treated. Abdominal ultrasound, plain abdominal X-ray, and CT are diagnostic imaging tools, but sometimes an additional surgical intervention must be considered. A primary diagnostic laparoscopy can be useful; conversion to open exploration is usually required to evacuate bowel spillage and perform the necessary repair [8].

## 2.11 Future Perspectives

The still relatively young field of robotic surgery is focused currently on reconstructive and technically challenging procedures. In urology, radical prostatectomy and pyeloplasty have gained widespread use over the last years. With growing experience in many centers, there is an increasing interest in other procedures where the advantages provided by the technology could be assumed. Nephron-sparing surgery and cystectomy with urinary diversion are examples for these upcoming points of interest [7, 25].

Especially in partial nephrectomy, further developments may help to make surgery even more precise; also future indications could probably be expanded to larger tumors. These developments could include new robotic instruments, combining of techniques like cryoablation or radiofrequency ablation with robotic technology and the use of virtual imaging data acquired before or during the procedure [19, 24, 36, 83].

The rapid evolution of technical possibilities will offer urologic surgeons numerous new perspectives over the next years.

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