# Chapter 8
# Contemporary Surgical Approaches for Small Renal Tumors

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## Introduction

Current guidelines on the management of renal tumors recommend the use of nephron-sparing approaches, such as thermoablation and partial nephrectomy, for patients presenting with a small renal tumor in need of treatment [1, 2]. These guidelines aim to avoid the sequelae of surgically induced chronic kidney disease, the risk of which is directly related to the amount of resected or treated normal renal parenchyma [3–5]. The most definitive method of nephron-sparing surgery is partial nephrectomy. First described using an open approach [6, 7], partial nephrectomy for small renal tumors is now most commonly performed by minimally invasive techniques including laparoscopic and robotic surgery [8]. When compared to the conventional open surgical technique, minimally invasive partial nephrectomy has resulted in significantly less postoperative pain, shorter hospital stays, earlier return to work and daily activities, and a more favorable cosmetic result [9, 10]. Additionally, oncologic outcomes appear to be equivalent to that of open surgery [11–13].

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## Laparoscopic Partial Nephrectomy

The first reports on the feasibility of laparoscopic renal surgery were published in the 1990s [14, 15]. Laparoscopic partial nephrectomy is now commonly performed worldwide. Two basic approaches for laparoscopic partial nephrectomy have been described: transperitoneal and retroperitoneal approach.

*Transperitoneal Approach* When performing transperitoneal laparoscopic partial nephrectomy, the patient is typically placed in modified flank position with 60° of flexion (Fig. 8.1). A four- or five-port approach may be used. A primary port 10 or 12 mm is placed lateral to the rectus muscle at the level of the umbilicus. The next port is placed lateral to the rectus muscle and just inferior to the costochondral margin, and the other port is inserted at the midaxillary line near the tip of the 11th rib. A 5-mm trocar is placed between the two working trocars in the posterior axillary line for the assistant. For right-sided procedures, a 5-mm trocar is often placed in the upper midline near the xiphoid process to accommodate a traumatic locking grasper forceps that can grasp the diaphragm and hold the liver up exposing the upper pole of the kidney. After obtaining pneumoperitoneum, the pressure is maintained at 15–20 mmHg.

Once the colon is mobilized, the ureter and gonadal vein are identified. On the left side, the ureter and the gonadal vein are retracted laterally. While on the right side, the gonadal vein is kept medially, and only the ureter is retracted laterally. The dissection is carried cephalad along the psoas muscle, and the renal hilum is dissected. The renal artery and vein are dissected to facilitate further application of laparoscopic bulldog clamps to each vessel (Fig. 8.2). Prior to incising beyond the

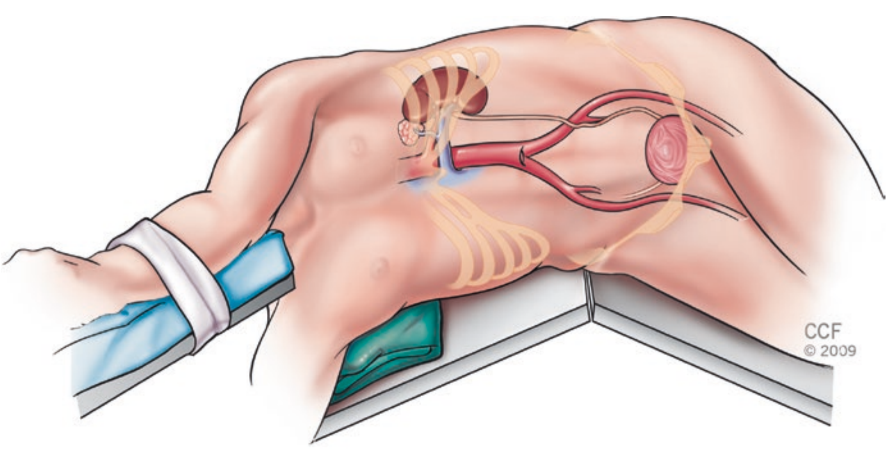


**Fig. 8.1** Patient positioning for the transperitoneal approach to minimally invasive partial nephrectomy. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

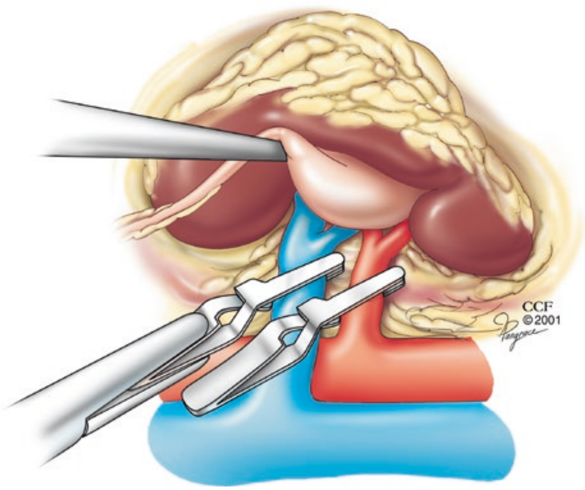


**Fig. 8.2** Clamping of the renal hilum during minimally invasive partial nephrectomy using bulldog clamps. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

renal capsule, all necessary materials, including sutures and instruments, should be confirmed to be at hand before proceeding.

Gerota's fascia is dissected off the kidney, preserving the perirenal fat in contact with the tumor. Intraoperatively, a flexible laparoscopic color Doppler ultrasound probe can be introduced through a 10- or 12-mm port and positioned in direct contact with the surface of the kidney. Information regarding tumor size, depth of intraparenchymal extension, and distance from the collecting system is obtained. The renal capsule is scored circumferentially with monopolar scissors. Regional hypothermia may be employed with ice slush only when prolonged ischemic times are anticipated (technique below). Bulldog clamps are then inserted. The renal artery, and if necessary the vein, is then clamped in the event that both vessels require clamping. The renal artery is clamped prior to the vein. The tumor is then excised with cold scissors, and the resection is carried deep to the tumor so that an adequate resection margin is achieved. This commonly requires entry into the renal collecting system.

The closure of the renal defect proceeds in two layers. The first layer includes the tumor bed and, if opened, the collected system. A single running suture is used for this deep layer and secured on both ends by Hem-O-Lock clip (Teleflex, Wayne, PA). The second suture layer includes the remaining kidney parenchyma. For this layer we use the sliding-clip technique [16]. A 0 or number 1-polyglactin suture is prepared on the back table by cutting to a length of 15 cm. A knot is tied at the end of the suture, and a Hem-O-Lock clip is placed proximal to the knot so that the clip will not slide off of the suture when pulled tight. The capsular stitches are then placed, after which the assistant places a Hem-O-Lock clip on the loose end, a few centimeters from the capsule. The Hem-O-Lock clip is then slid into place using the needle driver, providing tension that is under complete control of the surgeon. Once the defect is closed, the bulldog clamps are released. The defect can be covered with oxidized cellulose (Surgicel, Ethicon Inc., Somerville, NJ, USA) and/or a fibrin sealant (Evicel, Ethicon, Inc., or Vitagel, Orthovita, Malvern, PA, USA). Gerota's fascia may be closed by using Hem-o-Lok clips.

The specimen is next removed with the aid of a laparoscopic entrapment sac that is introduced by the assistant. Care must be taken to make the extraction incision large enough to avoid fracturing the specimen, possibly preventing accurate histopathologic examination for margin status and staging. All 12-mm incisions are closed with 0-Vicryl suture by using the Carter-Thomason device (Inlet Medical Inc., Eden Prairie, MN, USA). Finally, a surgical drain may be placed at the discretion for the surgeon. We find a drain is helpful for screening for a urine leak, a complication that is known to occur in 1% to 3% of minimally invasive partial nephrectomies [17, 18].

*Retroperitoneal Approach* Surgical approach (transperitoneal or retroperitoneal) is determined by surgical goals, patient medical and surgical history, and surgeon experience. In performing the retroperitoneal approach, a major benefit is avoidance of intra-abdominal organs and adhesions. An understanding of the retroperitoneal anatomy is crucial when attempting this surgical approach, since the retroperitoneal space provides fewer landmarks than the intraperitoneal space. This approach can be particularly convenient for perihilar and posterior upper pole tumors. It had been associated with reduction in operative time and hospital stay [19].

With the retroperitoneal approach, the patient is placed in a full flank position (Fig. 8.3). The flank should be directly over the table break. The table is flexed adequately to open the space between the 12th rib and the iliac crest. The retroperitoneum is then balloon dilated (Fig. 8.4), and three 12-mm ports are placed (Fig. 8.5). The renal artery and vein are dissected to facilitate application of laparoscopic bulldog clamps to each vessel. Similar to the transperitoneal approach, the tumor is excised and the renal parenchyma is repaired.

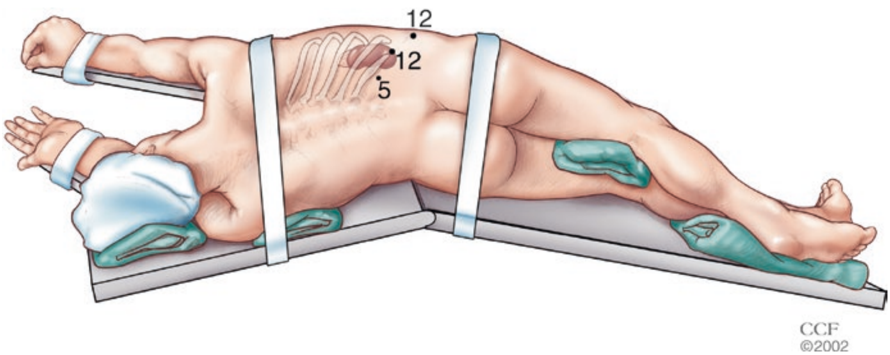


**Fig. 8.3** Patient positioning for the retroperitoneal approach to minimally invasive partial nephrectomy. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

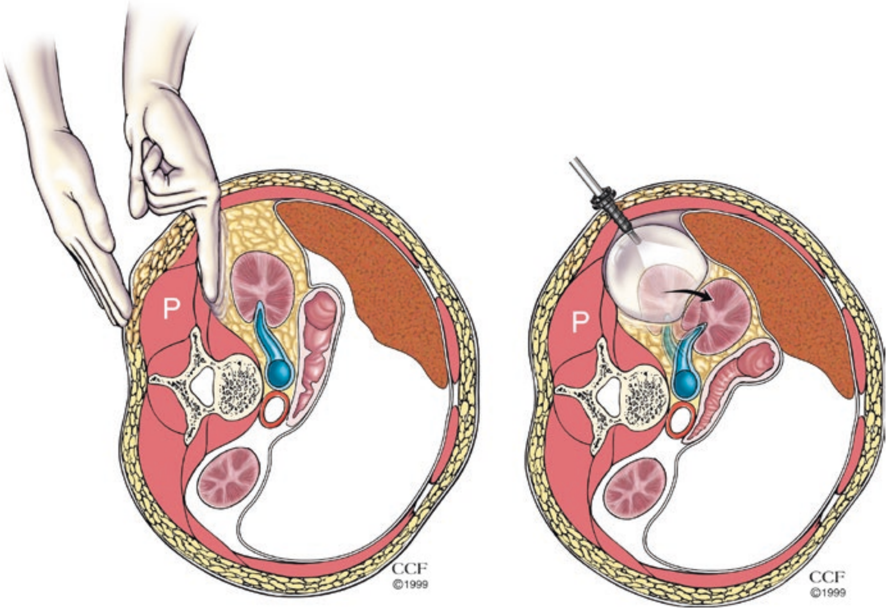


**Fig. 8.4** Blunt and balloon dissection of the retroperitoneal space. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

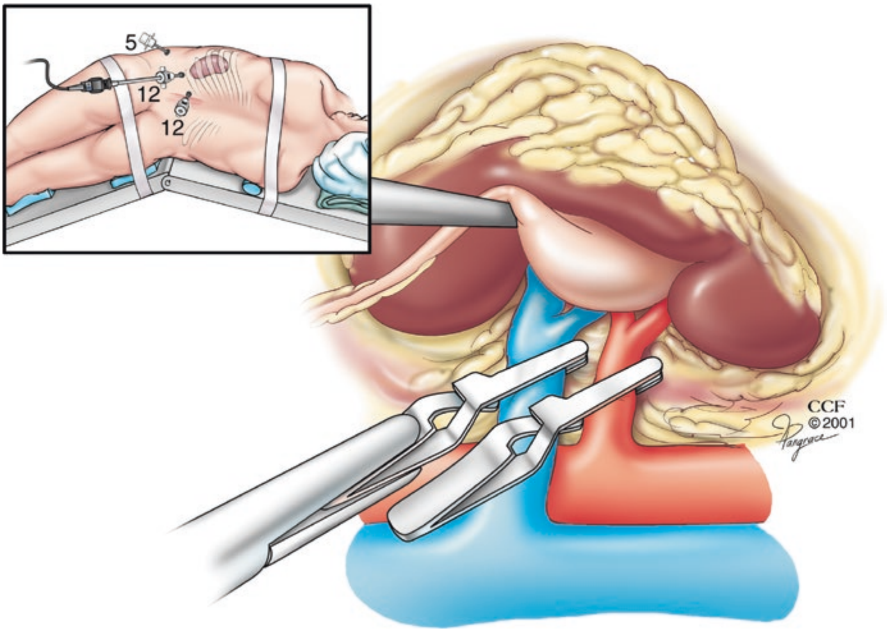


**Fig. 8.5** Trocar position and bulldog clamp placement during laparoscopic retroperitoneal partial nephrectomy. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

## Robotic-Assisted Laparoscopic Partial Nephrectomy

Robotic-assisted laparoscopic partial nephrectomy was initially reported by Gettman et al. in 2004 [20]. The robot offers two main advantages over conventional laparoscopy. First, the binocular camera allows for a three-dimensional view of the operating field leading to improved depth perception by the surgeon. Second, the "wrist" of the robotic arms has 7 degrees of freedom, which allows the surgeon improved control over certain aspects of the operation, most importantly precise suturing with minimal tissue manipulation. The technological advantages of robotic-assisted partial nephrectomy over conventional laparoscopy have allowed a shorter learning curve [21–24] and have in turn led to the wider use of partial nephrectomy for the treatment of renal tumors [8]. As with laparoscopy, robotic partial nephrectomy can be performed with either a transperitoneal or retroperitoneal approach. Regardless of surgical approach, the procedure is commonly performed using a three-arm configuration with a 30° down scope, ProGrasp forceps, hot monopolar curved scissors, hook cautery, and large needle drivers.

Concerning differences between surgical platforms (da vinci Si vs Xi from Intuitive Surgical Inc., Sunnyvale, CA, USA), there is no evidence to suggest the superiority of one system over the other. Kallingal et al. were the first to describe their operative technique with the newer Xi system [25]. They found that the procedure with the Xi system could be safely performed with acceptable perioperative and pathologic outcomes. Abdel Raheem et al. compared the Si and Xi surgical platforms [26]. The authors observed shorter docking times with the Xi robot but no differences in terms of significant intraoperative advantage, perioperative complications, or short-term functional outcomes between the two robotic systems. From the oncological and renal function point of view, all tumors were excised successfully with negative surgical margins.

*Transperitoneal Approach* The patient is positioned in a modified flank position at approximately 60°. Pressure points are carefully padded with pillows and foam pads, and the patient is secured to the table with tape. The surgical table is mildly flexed and positioned in slight Trendelenburg position.

A similar port configuration is used for both right and left sides, as illustrated in Fig. 8.1. The abdomen is insufflated to 15 mmHg with a Veress needle at the lateral border of the rectus muscle across from the 12th rib. This serves later as the site for a 12-mm port through which the robot scope is inserted. An 8-mm robot port is placed at the lateral border of the ipsilateral rectus muscle, about 3 cm below the costal margin. A second 8-mm robot port is placed approximately 5–7 cm cephalad to the anterior superior iliac spine. An assistant 12-mm port is placed along the lateral border of the rectus muscle in the lower abdominal quadrant. On the right side, an additional 5-mm port is placed in the subxiphoid area to retract the liver (Fig. 8.6). Port configuration can vary based on tumor location to optimize the working angles. For upper pole tumors, all the ports can be shifted 1–2 cm cephalad. Moreover, an extra 5-mm assistant port between the camera and the right robot port can be placed to allow the assistant better access to the operative field. For posterior tumors, all the ports can be shifted medially, as the kidney needs to be mobilized to allow access to its posterior aspect. The robot is positioned over the patient's shoulder so that its axis makes an obtuse angle in relation to the patient's axis to have the camera oriented in line with the kidney (Fig. 8.7). The bedside assistant stands next to the abdomen.

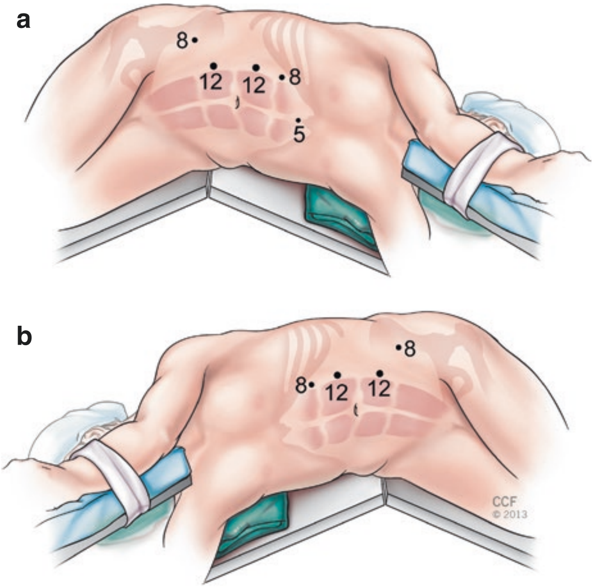


**Fig. 8.6** Port configuration used during robot-assisted laparoscopic partial nephrectomy. (**a**) Right-side port placement. (**b**) Left-side port placement. 12-mm port for the robotic scope, 8-mm ports for the robotic instruments, 12-mm port for the assistant, and 5-mm port for liver retraction. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

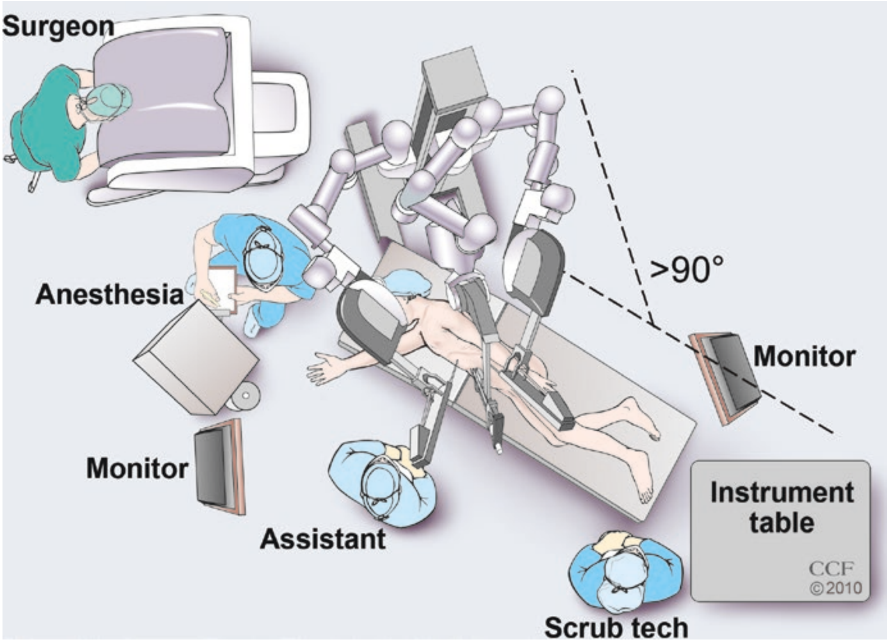


**Fig. 8.7** Operating room setup and robot docking for transperitoneal partial nephrectomy. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

On the right side, liver retraction is achieved by introducing a locking Allis clamp through the 5-mm subxiphoid port. With a monopolar curved scissors in the surgeons' right hand and a ProGrasp forceps in the left hand, the peritoneum is sharply incised along with the white line of Toldt. The bowel is mobilized medially, developing a plane anterior to Gerota's fascia and posterior to the mesocolon by using both sharp and blunt dissection. Attachments to the spleen or liver are released as necessary. It is important to remain outside Gerota's fascia during bowel mobilization. On the right side, there is no need for extensive mobilization of the bowel to expose the renal hilum. During the mobilization of the duodenum medially, the use of cautery is minimized. The gonadal vein is an important anatomic landmark when proceeding toward the renal hilum. On the right side, the gonadal vein is kept medially toward the vena cava, whereas on the left side, the gonadal vein is lifted along with the left ureter to expose the lower margin of the left renal hilum.

Dissection proceeds along the psoas muscle with anterior elevation of the ureter and/or gonadal vein to identify the renal hilum (Fig. 8.8). The renal vein can be identified by tracing the gonadal vein proximally to its insertion in the renal vein on the left side or to its insertion in the inferior vena cava just caudal to the hilum on the right side. A flexible robotic Doppler probe (Vascular Technology Inc., Nashua, NH, USA) can be used to identify hilar vessels before clamping, especially in cases involving

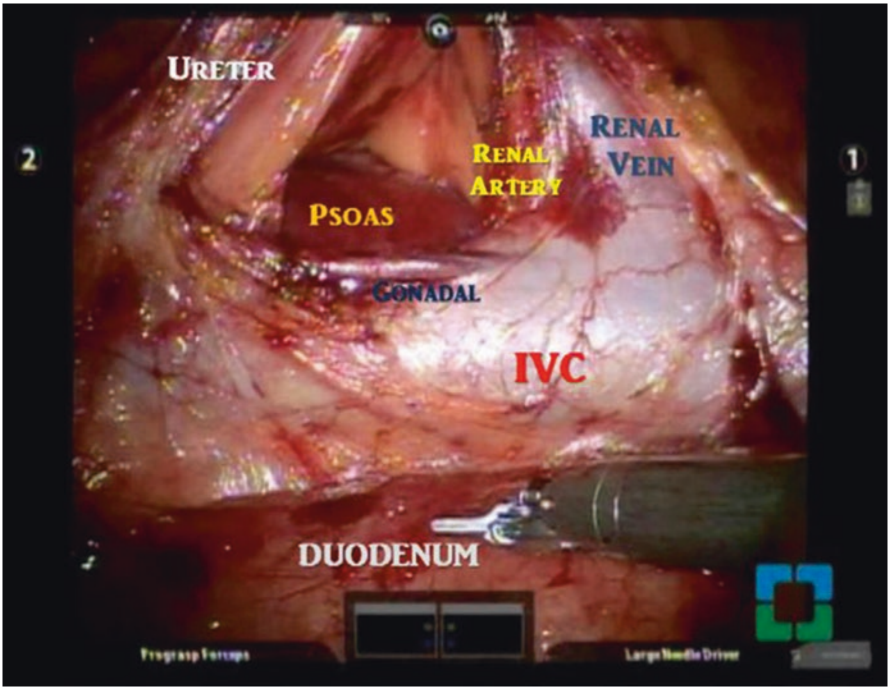


**Fig. 8.8** Surgical landmarks during transperitoneal robot-assisted partial nephrectomy. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

multiple renal arteries or early branching. The main hilar vessels are circumferentially dissected to allow adequate placement of bulldog clamps. It is important not to miss early arterial branching that is more common on the right side, especially if occlusion of the renal vein is planned, as this may lead to kidney congestion and may result in more bleeding. Once the main landmarks are identified, manipulation of the ureter should be avoided to minimize risk of injury or devascularization. If an early branching or bifurcation is suggested by the CT scan, the dissection should be carried medially. While dissecting the hilum, the assistant can provide countertraction by using suction. In our experience, we have found the hook cautery to be particularly useful at this step of the operation and can be used according to the surgeon's preference.

Once the hilum is dissected, Gerota's fascia is opened in an area far from the tumor to find the capsule, and dissection is performed along the renal capsule until the mass is exposed. A clue that one is approaching the tumor area is the presence of adhesions. The fat is then cleared circumferentially around the mass, allowing for visualization of 1–2 cm of normal parenchyma for future renal reconstruction. Gerota's fascia atop the mass should be preserved to assist in histopathologic staging and also to use as a handle for retraction. A laparoscopic ultrasound probe is used to plan the excision margins by allowing accurate identification of the location, depth, and borders of the tumor (Fig. 8.9). A recently introduced, drop-in, flexible, ultrasound probe (ProART

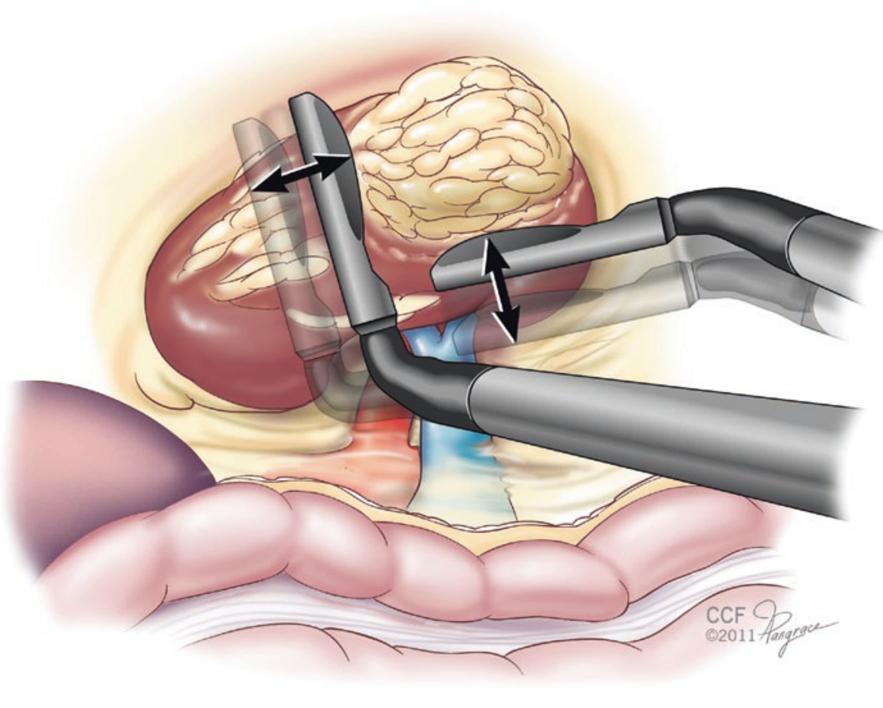


**Fig. 8.9** Flexible ultrasound probe being used during robotic partial nephrectomy. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

Robotic Drop-In Transducer 8826; BK Medical, Peabody, MA, USA) was specifically developed for robotic surgery and can be directly controlled by the console surgeon by grasping a notch on its ventral aspect. Live intraoperative images are shown as a picture on picture display on the console screen using the TilePro functionality of the da vinci surgical system. To define the border of the tumor, the ultrasound probe is oriented parallel to the tumor border. Margins of resection of the renal capsule are scored with cautery to delineate the resection boundaries.

Renal vasculature clamping is achieved using bulldog clamps. In selected cases, resection may be performed by clamping the renal artery only. Recently, robotic bulldog clamps (Scanlan International, St. Paul, MN, USA), applied by the console surgeon using the robotic ProGrasp, have also become available. As with the laparoscopic approach, the renal hilum is clamped and the tumor resected along the previously scored margin using cold scissors (Fig. 8.10). The bedside assistant can use suction to clear the resection bed, enabling improved visualization while applying slight counter retraction, as needed.

Renorrhaphy is performed in two layers with robotic needle drivers and the sliding-clip technique [16]. A 20-cm 2-0 Vicryl suture on an SH-1 needle (Ethicon Endo-Surgery, Somerville, NJ, USA) with a knot and Hem-o-Lok clip applied to the free end is used as a running suture of the tumor excision bed to oversew larger vessels and entries into the collecting system. The suture is brought through the renal capsule with the final throw and secured with two sliding Hem-o-Lok clips. The renal capsule is reapproximated using a continuous, horizontal mattress 0-Vicryl suture on a CT-1 needle with a sliding Hem-o-Lok clip placed after each suture is passed through the capsule (Fig. 8.11). After completion of the renorrhaphy, the hilum is unclamped, and the resection bed is inspected for hemostasis with pneumoperitoneum pressure lowered to 6 mm Hg. Hem-o-Lok clips may be cinched down further to secure hemostasis. Whenever possible, the hilum is unclamped before capsular suturing in an early unclamping technique to minimize warm ischemia time. Further steps for specimen retrieval, Gerota's fascia approximation, Jackson-Pratt placement, and incision closure are similar to the techniques described in the laparoscopic section above.

*Retroperitoneal Approach* The patient is placed in the full flank position and the table fully flexed to increase the space between the 12th rib and iliac crest. Low-profile supports, e.g., rolled blankets, are preferred to bulky padding to avoid clashing with the robotic arms. The spine and hip must be positioned in a straight line and the spine fully exposed to allow space for placement of the lateral robotic arm. The dependent arm is padded and secured to an arm board, which is tilted toward the head as much as possible. After positioning, the table is rotated, so that the patient side-cart can be docked straight over the patient's head. The patient is then draped and the bed-side assistant stands beside the abdomen.

A 12- to 15-mm length incision for the camera port is made in the midaxillary line, 2 cm above the iliac crest. The external oblique muscles are separated using retractors to expose the lumbodorsal fascia. Access to the retroperitoneum is gained by perforating the dorsal lumbar fascia. Blunt finger dissection is useful to create

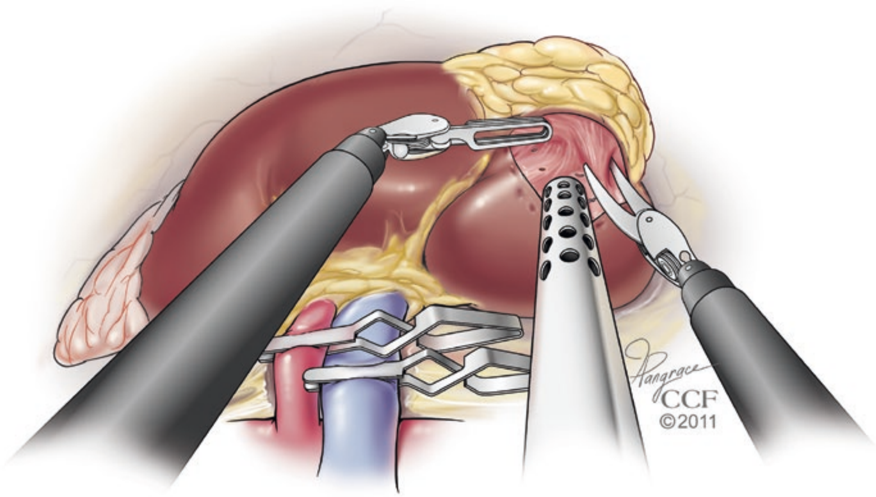


Fig. 8.10 Resection of the tumor during robotic partial nephrectomy. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

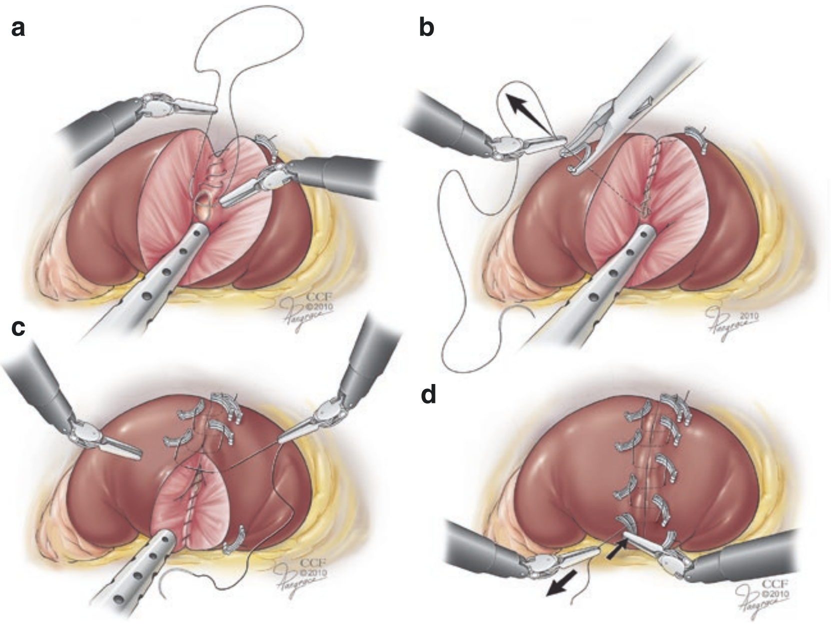


**Fig. 8.11** Renorrhaphy following tumor excision during robotic partial nephrectomy. The reconstruction is performed in two layers using the sliding-clip technique. **a**) 2-0 Vicryl 6-inches suture on a SH-1 needle with a knot and Hem-o-Lok clip applied to the free end is used as a running suture to oversew the collecting system as well larger vessels from the tumor excision bed; **b**) sutures are brought through the renal capsule with the final throw and secured with two sliding Hem-o-Lok clips; **c** and **d**) a continuos horizontal mattreess is used for reapproximation the renal capsule with a 0-Vicryl suture on a CT-1 needle and a sliding Hem-o-Lok clip placed after each suture is passed through the capsule. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

the working space anterior to the psoas. Caution is taken to avoid entry to the peritoneal cavity. The operative space in the retroperitoneum is then developed with a balloon dilator (Fig. 8.4). By generating this space, intraperitoneal structures such as liver, spleen, and colon are deflected medially. The camera is then placed to inspect the retroperitoneal space. Two 8-mm incisions for the robotic working arms are made medial (along the lateral border of the paraspinous muscle) and lateral (inferior to the 11th rib), to the camera port. In case of obese patients, ports need to be shifted laterally and cephalad. The assistant 12-mm trocar is placed inferior and medially to the anterior robotic port and should be no closer than 6 cm to avoid conflict with the anterior robotic arm (Fig. 8.12). The robot is docked directly over the patient's head parallel to the spine.

The first step in exposing the kidney is the management of paranephric fat. This fat is carefully dissected off of Gerota's fascia and placed in the lower retroperitoneum. Care is taken medially and anteriorly where the peritoneum can be easily entered. Great attention must be taken to identify the peritoneal reflection anteriorly to avoid blind trocar passage into the peritoneal cavity. Next, Gerota's fascia is incised just above the psoas muscle exposing the perinephric fat and kidney. Dissection is then carried along the psoas muscle elevating the kidney and perinephric fat. The ureter is typically encountered first medial to the incision in Gerota's

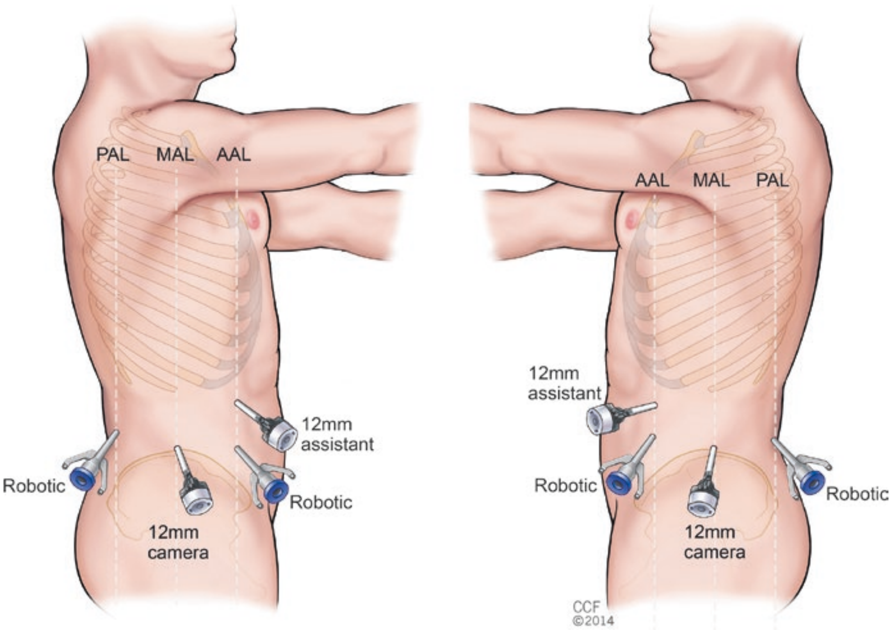


**Fig. 8.12** Positioning and trocar placement for retroperitoneal robotic partial nephrectomy. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

fascia and then followed up toward the hilum. The renal artery is typically encountered first, unlike the transperitoneal approach.

Next, the renal artery is exposed to allow a bulldog clamp on the artery. The renal vein is rarely clamped and only if the tumor is large or centrally located. A 5-mm margin is then scored circumferentially around the tumor. The tumor is excised under warm ischemic conditions, and judicious suctioning is used to maintain a clear operative field allowing the identification of tumor if encountered. Aggressive suctioning in the retroperitoneal space can lead to rapid desufflation and should be avoided. The renal defect is reconstructed in two layers as described above.

## Modifications to Robotic Partial Nephrectomy

*Robotic Partial Nephrectomy with Intracorporeal Renal Hypothermia* There is general consensus in the literature that when performing a partial nephrectomy, warm ischemia time should be limited to 20–25 min [27, 28]. When a longer ischemia time is expected, the use of renal cooling is encouraged as it is known to improve renal tolerance for ischemia up to 45 min [29]. It has been shown that cold ischemia decreases oxidative harm to the kidney secondary to direct hypoxia and subsequent reperfusion [30–32]. During open surgery, ice slush cooling is routinely used. However, renal cooling during minimally invasive partial nephrectomy is more challenging. Different techniques such as endoscopic retrograde ureteric cooling [33], arterial infusion [34], and cooling via renal surface irrigation [35] have been described. The use of intracorporeal ice slush to obtain renal hypothermia during robotic partial nephrectomy was first described by Rogers and colleague with direct instillation of ice slush onto the surface of the kidney [36]. Thereafter, Kaouk and coworkers described a simplified modification of that technique that will be detailed below [37, 38].

Patient positioning, port placement, and docking of the robot are similar to the previously described technique for transperitoneal partial nephrectomy. An additional 12-mm laparoscopic port is placed along the midaxillary line and the costal margin. This port is used for introduction of the temperature probe and ice slush during cooling phase of the procedure.

Sterile ice slush is created in an ice slush machine (Hush Slush System; Ecolab Inc., St. Paul, MN) and constantly stirred manually to keep ice consistency uniform. Five 20- or 30-mL syringes are modified by cutting off the nozzle ends of the barrels with a scalpel. The rubber on the ends of the plungers are also removed. The modified syringes are then prefilled with ice slush in preparation for instillation. A lateral 12-mm accessory port is placed directly above the kidney. The port is removed, and the needle temperature thermocouple (Mon-a-Therm; Covidien, Mansfield, MA) is introduced via the port site using a laparoscopic grasper and placed in the renal parenchyma away from area of planned excision. The 12-mm accessory port is reintroduced alongside the thermocouple wire following the positioning of the thermocouple. Renal and core body temperatures (via esophageal probe) are monitored during the procedure. A 4- × 18-cm laparoscopic sponge is then placed surrounding the kidney, creating a barrier between the kidneys and neighboring bowel. The mobilized kidney is overturned medially, and ice slush is introduced through the 12-mm port posterior to the kidney and packed on top of the psoas muscle and on the renal parenchyma (Fig. 8.13). The kidney is allowed to cool for several minutes before clamping the renal hilum. The hilum is clamped with bulldog clamps placed on the renal artery and vein sequentially. More ice slush is introduced, and the kidney is allowed to cool further, until parenchymal temperatures are <20 °C. Of note, it is imperative to clamp both the artery and the vein to achieve renal parenchymal cooling (Fig. 8.14).

Using a suction or irrigation device, ice slush is then cleared from the renal tumor and surrounding renal capsule. The tumor is then resected along the previously scored margin using cold scissors. Renorrhaphy is performed as previously described. The renal parenchymal temperature is monitored in real time, and further ice slush is introduced as needed to keep kidney temperature under 20 °C and to provide a constant coverage of ice over the kidney beyond area of resection. The

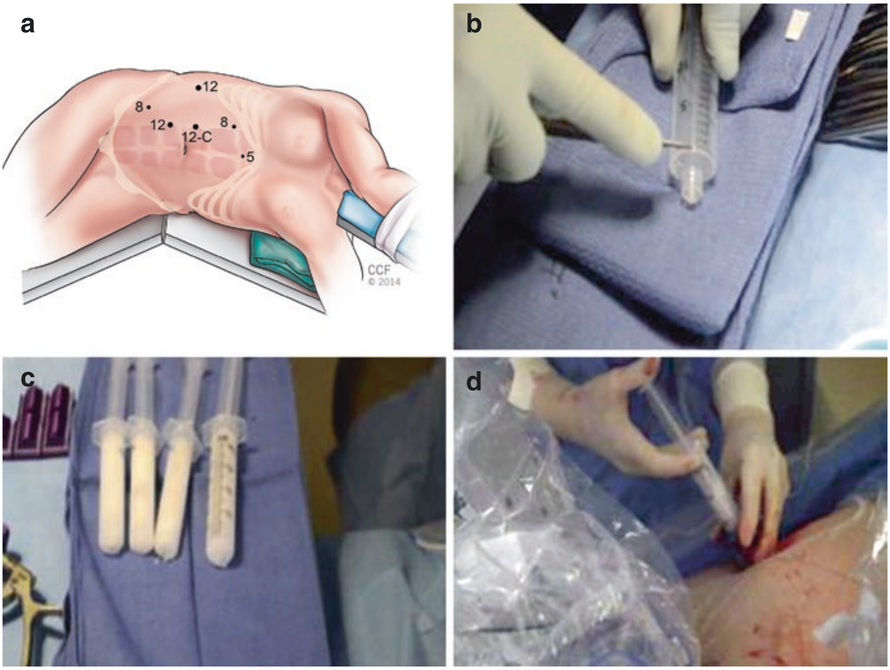


**Fig. 8.13** (**a**) Patient positioning and port placement for intracorporeal hypothermia during minimally invasive partial nephrectomy. (**b**) A 20- or 30-mL syringe is modified by cutting off the nozzle end of the barrel with scalpel. (**c**) The modified syringes are then prefilled with ice slush in preparation for instillation. (**d**) The ice is instilled through the accessory 12-mm port. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

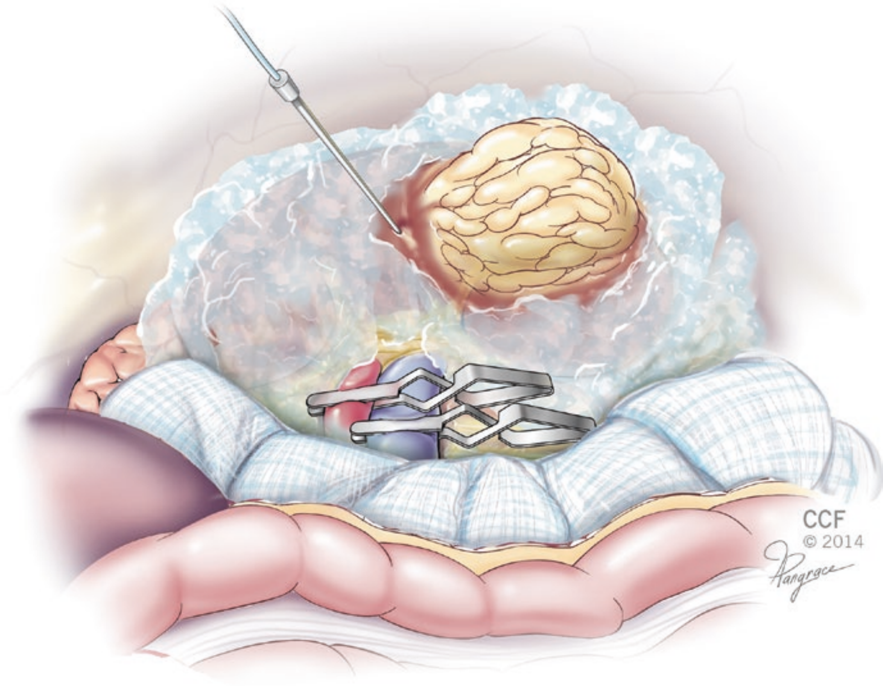


**Fig. 8.14** Illustration of a kidney following placement of ice slush just prior to tumor resection. A thermocouple is used to measure the temperature of the renal parenchyma. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

hilum is unclamped and the renorrhaphy is inspected for hemostasis. Any additional remaining ice can be removed by suction or by transfer into the entrapment sac. A Jackson-Pratt drain is placed through a lower lateral port to also aid with the evacuation of melted ice slush.

*Fluorescence Image-Guided Robotic Surgery* Robotic surgery utilizing near-infrared fluorescence imaging is a technology with emerging applications in urologic surgery [39]. During partial nephrectomy this technology has the potential to enhance discrimination between normal renal parenchyma and tumor allowing for a more accurate dissection. Furthermore, this technology has the potential to aid in the visualization of the renal vasculature allowing for selective arterial clamping [40].

Injected indocyanine green (ICG, Akorn, Lake Forest, IL) is a fluorescent tricarbocyanine dye that emits light in the near-infrared wavelength (700–850 nm) after activation by a light-emitting diode [41]. ICG binds to albumin when intravenously injected and therefore remains primarily in the vasculature. The light emitted is not visible to the human eye and requires use of a charge-coupled device camera which has been integrated into the da vinci surgical system. Using what is known as the

Firefly imaging system, the surgeon can switch between standard (white) light and fluorescence-enhanced views in real time [42].

ICG is diluted to a 2.5-mg/mL solution immediately before each case and administered in discrete boluses intravenously by the anesthesia team as directed by the surgeon. After scoring of the parenchyma surrounding the tumor, ICG is administered at a dose of 5–10 mg intravenously. The maximum dosage is 2 mg/kg, and it must be given within 6 h of reconstitution. The intravenous injection is given immediately before clamping the renal artery. The initial pass of the dye is seen as fluorescence of the artery and then the renal vein, followed by the renal parenchyma. The tumor generally has a lower level of fluorescence than the normal surrounding kidney tissue. Tumor excision is started along the prescored area on the kidney surface and deepened down into the renal parenchyma. The console view can be switched between the standard white light vision and near-infrared vision at the discretion of the operating surgeon to confirm the plane of excision between tumor and parenchyma to avoid entry into the tumor [43].

Near-infrared fluorescence imaging with ICG can also be used to facilitate selective arterial clamping. In this setting, local ischemia to the tumor and immediate surrounding renal segment is induced by applying mini-bulldog clamps (Scanlan International, St. Paul, MN, USA) to secondary-, tertiary-, or quaternary-level arterial branches. Well-perfused renal parenchyma appears fluorescent green under near-infrared fluorescence imaging. Ischemic tissue will not fluoresce, verifying the correct arterial branch has been controlled. If peritumoral arterial flow continues despite selective arterial clamping, either additional arterial branches may be sought and selectively clamped or complete arterial clamping may be utilized.

*Robotic Laparoendoscopic Single-Site Partial Nephrectomy* Laparoendoscopic single-site surgery (LESS) has been developed to further minimize the morbidity associated with multiport minimally invasive surgery. The single-site approach to LESS surgery requires only one entry point to the body. By reducing the number and length of skin and fascial incisions, it is hypothesized that patients will experience less pain, faster convalescence, and improved cosmesis following surgery [44–47]. In recent years, the advantages offered by robotic technology have been combined with those of LESS (Fig. 8.15). The majority of surgical steps for preforming partial nephrectomy with robotic LESS are similar to what has been described earlier. However, several modifications are required in order to accommodate the limited available working space of LESS.

Subtle differences exist when comparing traditional robotic docking with docking used for robotic LESS procedures. In regard to the robotic platform, the da vinci Si or Xi models are preferred over the S model secondary to enhanced visualization, improved ergonomic control at the surgeon console, and, most importantly, a more-compact, sleeker bedside profile which assists with minimizing external clashing of the robotic arms [48, 49]. For robotic LESS procedures, typically only two robotic instrument arms are used due to limited working space.

A number of technical modifications have been described in order to minimize external clashing of instrument arms during LESS. For example, the “chopstick”

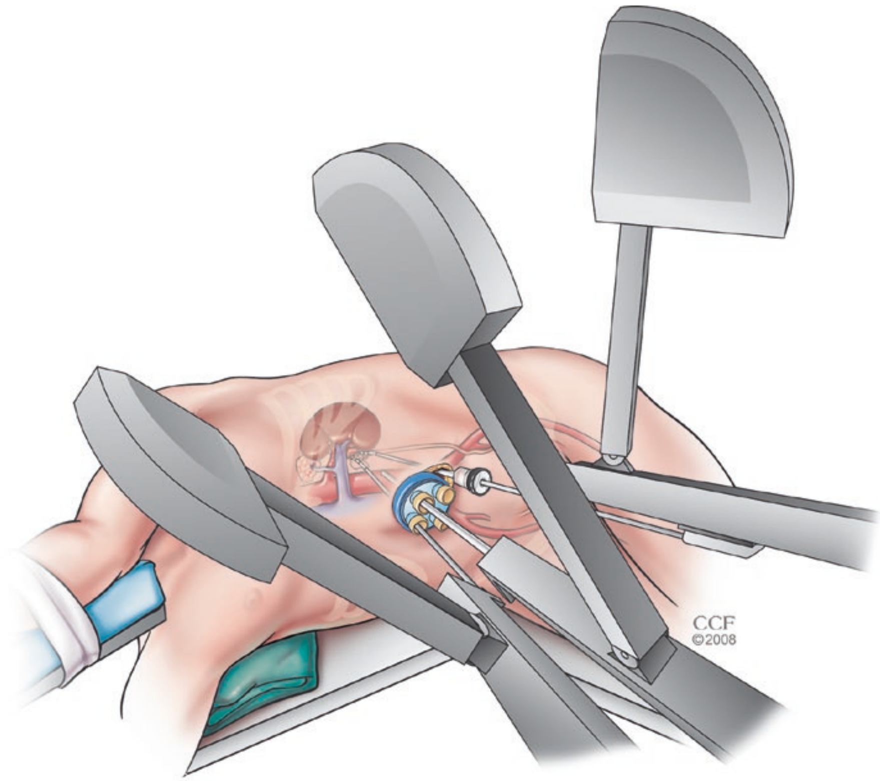


**Fig. 8.15** Robotic laparoendoscopic single-site surgery. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

technique popularized by Joseph et al. minimizes external instrument clashing by crossing the instruments at the level of the fascia in order to create more space between the robotic arms outside of the body [50]. This technique was previously employed during traditional LESS but has proven to be very challenging secondary to the crossing of instruments resulting in "reverse handedness." This benefit of using the robotic platform is that the robotic instruments are controlled electronically, allowing the left and right hand joystick hand effectors to be interchanged, thus removing this challenge (Fig. 8.16).

In addition to these technical modifications, a variety of multichannel access ports have been described for use during robotic LESS [51]. Additionally, an innovative device precisely designed for robotic LESS has been developed by da vinci surgical, known as the SP999 single-port system [52]. This system uses the same base of the patient side cart as the da vinci Xi robotic system and has been adopted for use with a single arm that controls an articulating endoscopic camera and three double-jointed articulating endoscopic instruments which enter the patient through a multichannel robotic port (25-mm cannula) (Fig. 8.17).

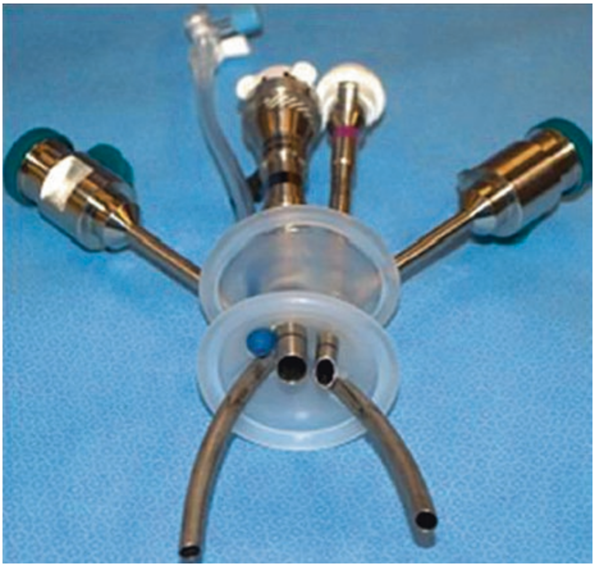

**Fig. 8.16** da vinci curved cannula system for robotic laparoendoscopic single-site surgery. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

A newer da vinci single-port surgical system has recently been developed (SP1098) and includes upgraded technology designed specifically for extraperitoneal single-site surgery [53–56]. Similar to the SP999, the SP1098 consists of three main components: a surgeon console, a patient side cart, and a vision cart. As before, four robotic manipulators, or instrument drives, that control the camera and instruments are mounted on an instrument arm that is attached to the patient side cart. The surgeon console is identical to the second-generation robotic system (SP999) with a foot pedal that allows control of the instrument arm. Unique to this robotic system is the ability to clutch and pivot the instrument arm about its remote center without moving each individual instrument. In effect, an instrument can be stationed at one location in the surgical field (e.g., for retraction), while the instrument arm is clutched and reoriented to a separate site, where the remaining instruments can be deployed without disturbing the stationary instrument. This improvement overcomes the constraint of multiple instruments entering the body through a fixed point, effectively expanding the workspace and improving maneuverability. The new vision cart is similar to the previous generation with upgraded resolution to accommodate the improved camera optics (Fig. 8.18).

These new single-port robotic technologies represent a step forward in minimally invasive surgery. It is unique as it allows for intracorporeal triangulation while eliminating instrument clashing seen with other methods of performing single-site surgery.

Because of space limitations and the size of the robot at the patient side, the standard approach to robotic kidney and adrenal surgery has been transperitoneal. However, posteriorly located kidney tumors are sometimes difficult to approach transperitoneally and require the kidney to be completely mobilized and flipped medially. The retroperitoneal approach has emerged as an alternative to


**Fig. 8.17** The da vinci SP999 single-port platform. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

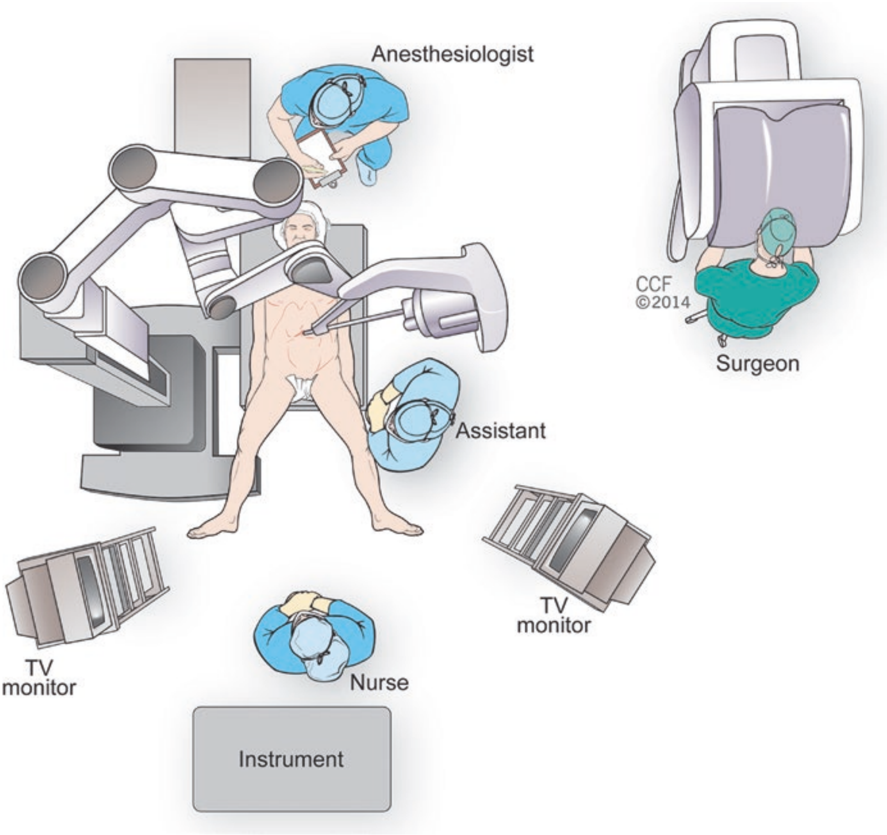


**Fig. 8.18** Operating room setup and robot docking for laparoendoscopic single-site renal surgery. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

transabdominal robotic adrenal and kidney surgery for posterior tumors. With the SP1098 system, approaching posterior and anterior tumors is feasible using a retroperitoneal access [56].

For transperitoneal renal surgery using the da vinci single-port system, the patient is positioned in a modified flank position at approximately 60°. A transumbilical incision or pararectal incision is made to allow the insertion of the 2.5-cm robotic port (Fig. 8.19). One 12-mm assistant port is placed through the same skin incision alongside the single robotic port.

For the retroperitoneal approach, the patient is placed in the full flank position and the table fully flexed to increase the space between the 12th rib and iliac crest. The port is placed at any point between the anterior axillary line and the paraspinous muscle (according to the location of the tumor, anterior or posterior), 2 cm above the iliac crest. The dissection and exposure are also the same for standard robotic partial nephrectomy.


**Fig. 8.19** The da vinci SP1098 single-port cannula. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 1999–2018. All Rights Reserved)

## Conclusion

With the advancement of new technologies, the surgical management of small renal masses has dramatically changed over the last several decades. Minimally invasive partial nephrectomy is now the standard of care and is most commonly performed using a robotic approach. Recent technological advancements aim to further improve visualization, decrease the impact of renal surgery on kidney function, and minimize the size and number of surgical incisions. There is no doubt that in the coming years, technical advancements will continue to improve the care and outcomes of patients presenting with a renal mass in need of surgical extirpation.

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