Radical Nephrectomy for Renal Cell Carcinoma: Non-robotic Minimally Invasive Approaches

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Introduction

Since the original report 150 years ago by Gustav Simon [1], the nephrectomy has undergone multiple landmark changes including the adoption of the retroperitoneal flank approach in the early twentieth century to reduce the incidence of intraabdominal complications, as well as a more radical, Halsted-esque, resection to remove the peri-renal fat and Gerota's fascia [2]. More recently, the use of laparoscopy has shown improved recovery after surgery [3, 4] and patient-reported quality of life [5]. Since the initial report of laparoscopic nephrectomy, minimally invasive surgery for renal cell carcinoma has rapidly evolved. We now aim to review the multiple, non-robotic based approaches that have been reported.

Contraindications

Few absolute contraindications to minimally invasive surgery for radical nephrectomy exist. Uncorrected coagulopathy increases the risk of peri-operative bleeding and should be corrected. Though, for patients on anti-coagulation for cardiac or vascular reasons, individual risk/benefit assessment should be undertaken as to whether these medications can safely be held. There have been reports that laparoscopic renal procedures can be safely performed during anti-platelet therapy [6]. In addition, the inability to tolerate general anesthesia [7] or pneumoperitoneum [8, 9],

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particularly in patients with advanced cardiopulmonary disease, would negate the ability to perform laparoscopy. Various adjustments to minimize the effects of insufflation, including working at lower pressures, use of helium instead of carbon dioxide [10], and use of specialized instruments [11] have been reported.

A thorough history and physical examination can identify potential difficulties during surgery and can help determine which approach would be best for the patient (laparoscopic vs open, transperitoneal vs. retroperitoneal). Prior transperitoneal or retroperitoneal surgery and obesity can increase surgical difficultly but do not preclude the ability to safely complete procedures. Ultimately, careful patient selection can optimize outcomes and minimize surgical risk.

Approaches

Transperitoneal

The transperitoneal approach is the traditional and most widely utilized minimally invasive method for performing a nephrectomy since the initial report by Clayman et al. [12] in 1991. It provides the largest working space of all approaches and is often the most familiar approach to urologists. Though, entry into the peritoneal cavity risks potential bowel or other intraperitoneal injury during insufflation or port placement.

After induction of anesthesia and appropriate tube placement (intravenous line, orogastric tube, urethral catheter), the patient is positioned in a modified (30–45°) flank position with the contralateral arm placed on an arm board and the ipsilateral arm secured in one of a number of positions (at patient's side, on a folded pillow across the chest or on a Kraus armboard). The patient is appropriately padded and secured to the table, allowing for table tiliting. Significant bed flexion and the use of the kidney rest is not required as with open surgery. Figure 1 demonstrates the above positioning with the arm secured at the patient's side. Pneumoperitoneum is obtained and ports are placed allowing for triangulation toward the 11th rib. Multiple trocar configurations have been reported [13]. The most common configuration utilizes ports located in the anterior axillary line at the level of the umbilicus and just off the costal margin approximately 1/3 of the way from the xiphoid to the umbilicus for instrumentation, as well as peri-umbilically for the camera. In the case of obese patients, trocar placement further lateral is required.

Retroperitoneal

The retroperitoneal approach was first described by Kerbl et al. in 1993 [14]. This technique more closely mimics an open flank approach given the avoidance of the bowel and the use of psoas muscle as a surgical landmark. Though, as noted in the

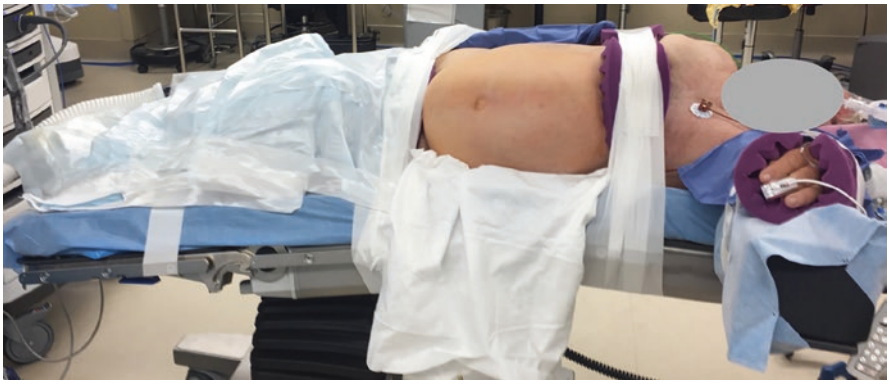

Fig. 1 Patient positioning for a right transperitoneal laparoscopic nephrectomy. A modified flank position is used with left (contralateral) arm on an arm board and right (ipsilateral) arm secured at patient's side

original report, the working space is substantially smaller than traditional laparoscopy, thereby reducing triangulation of the instruments and leading to increased instrument clashing.

The primary theoretical advantage of this approach is in avoiding the peritoneal cavity, thereby leading to earlier recovery of bowel function. This also negates the need for lysis of adhesions in patients with multiple prior intra-abdominal procedures. Though, a randomized prospective trail comparing traditional and retroperitoneal laparoscopic nephrectomy found only operative time to be different between the 2 approaches, but not blood loss, analgesic use, hospitalization time, or complication rate [15]. Disadvantages of this approach include the aforementioned smaller working envelope, as well as the subtlety of the anatomic landmarks. Considering the latter, entry too anterior can violate the peritoneum and risks colonic injury while too posterior risks bleeding from the psoas muscle or quadratus lumborum.

In this approach, patients are placed in a full flank position with an axillary roll to prevent a brachial plexus injury, as well as moderate bed flexion in order to open the retroperitoneal space between the 12th rib and iliac crest. An incision is made in the soft spot midway between the 12th rib and iliac crest which typically corresponds with the posterior axillary line. Dissection proceeds down to the lumbodorsal fascia which his opened and the retroperitoneum entered. Development of a potential space can then be performed bluntly with a finger, a balloon dilator, or with a laparoscope to create a working space along the psoas fascia. Typically, one of the instrument ports can then be placed posterior and cephalad to the camera port, just lateral to erector spinae muscles. Through this port, a blunt instrument can be used to dissect the peritoneum off the anterior abdominal wall medially, creating space for the other instrument port, often located just off the tip of the 12th rib. Figure 2 demonstrates port placement.

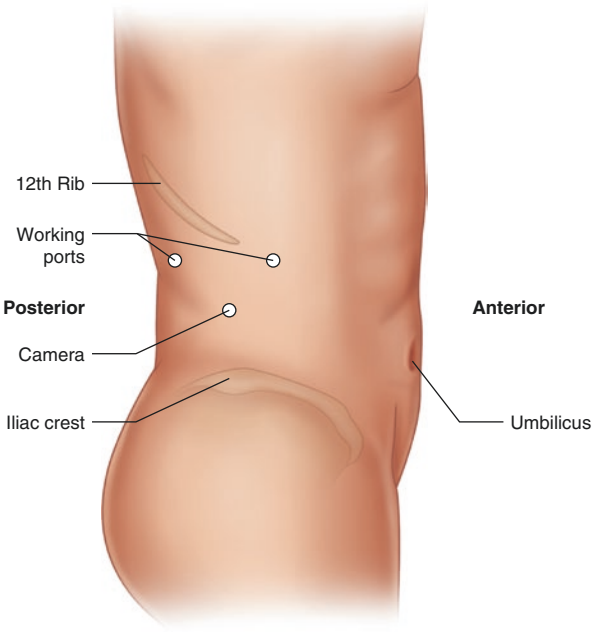

Fig. 2 Retroperitoneal laparoscopic nephrectomy port configuration. The camera port should be placed midway between the 12th rib and iliac crest and the working instrument ports placed cephalad. Care should be taken with placement of the posterior port to avoid the erector spinae muscles and the anterior port to avoid the peritoneal cavity

Hand-Assisted

The hand-assisted laparoscopic nephrectomy (HALN) was initially described by Nakada et al. in 1997 [16]. This technique combines the tactile feedback of open surgery with the minimal invasiveness of laparoscopy. Pneumoperitoneum is maintained by utilizing one of several commercial devices (e.g. *GelPort*, Applied Medical (Rancho Santa Margarita, CA, USA), *HandPort*, Smith and Nephew (Andover, MA, USA)) that allows a gloved hand to be inserted into the abdomen in an airtight manner (Fig. 3). Typically, the surgeon's non-dominant hand is placed intra-abdominally for retraction, palpation, and blunt dissection while the dominant hand manipulates a laparoscopic instrument via a traditional port. Figure 4 demonstrates the port placement for a right-handed surgeon performing a (a) right and (b) left hand-assisted nephrectomy.

The primary benefit of HALN is that it allows the technical challenges of laparoscopy to be easier for a more novice surgeon. Further, it allows for directly tissue palpation, making hilar anatomy more easily identifiable and allows for the treatment of masses with renal vein involvement [17]. Also, in the case of large tumors, hand-assisted retraction may be stronger and provide better exposure than laparoscopic instruments. In the event of a hilar injury, the presence of a hand in the abdomen can allow for better vascular control [18]. Traditional laparoscopic technique can be converted to hand-assisted by extending the non-dominant hand trocar incision and placing a hand-assist device.

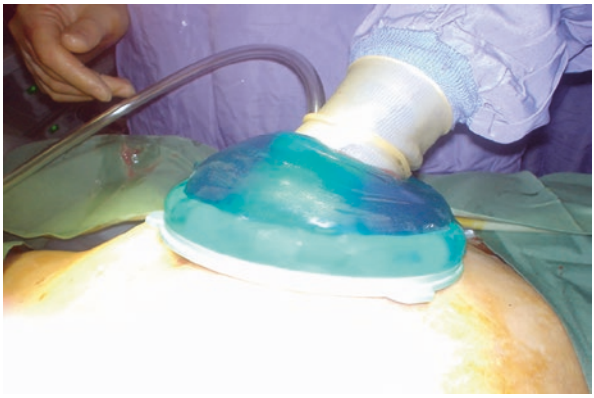

Fig. 3 Image of a commercial hand-assist device to maintain pneuoperitoneum with placement of a hand within the peritoneal cavity

Retrospective analysis of HALN compared to traditional laparoscopy is difficult as surgeons tend to elect for HALN for more challenging cases (large tumors or significant scaring). However, HALN has been showed to reduce operative time by 90 min [19]. A prospective randomized comparison demonstrated no difference in post-operative pain, hospitalization time, and complications [20]. Drawbacks of HALN include increased cost of the hand-assistance device, poorer cosmesis of the larger incision. There also the possibility of more pain and longer convalescence with the large incision, however, several studies have demonstrated these to be similar [18]. Ultimately, the HALN can be a valuable tool for challenging cases or as an intermediate means to manage intra-operative complications without conversion to open surgery [21].

Single-Site

Laparoendoscopic Single-Site (LESS) surgery refers to a laparoscopic technique that consolidates all ports within a single skin incision (typically peri-umbilically) [22]. The conceptual drive of LESS is minimization of skin incisions, and therefore, reduced port-related complications/pain and improved cosmesis. Non-randomized studies have demonstrated LESS is non-inferior to traditional laparoscopy with regards to peri-operative outcomes and minor improvements in post-operative pain and cosmesis [23]. A randomized trial demonstrated reduced recovery time and positive subjective cosmesis [24]. This technique has also be applied in robotic surgery [25].

LESS is a technical challenge and makes ergonomics unfavorable. Given the instruments are entering the abdominal cavity in close proximity, they often collide. Also, in some cases, the instruments must be crossed, leading to simple tasks becoming very technically demanding. Often, specialized equipment (curved, cross armed instruments) are required. Significant experience with laparoscopy is needed prior embarking on LESS.

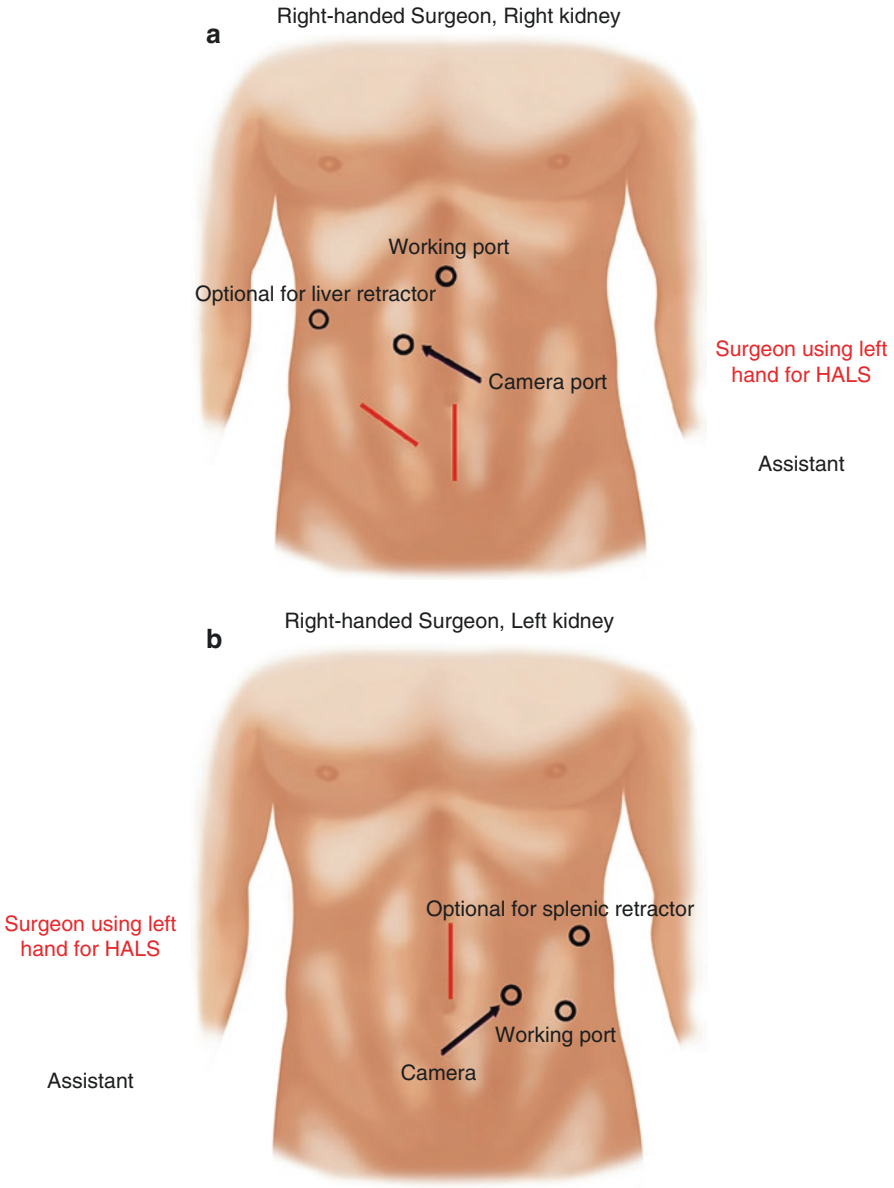

Fig. 4 Port configuration and surgeon/assistant positioning for a right-handed surgeon performing a (**a**) right and (**b**) left hand-assisted laparoscopic nephrectomy. Note, the red lines represent the location of the hand-assist device while circles represent the placement of traditional laparoscopic ports

LESS has been utilized extensively for laparoscopic donor nephrectomies as these tend to be healthy patients with favorable renal anatomy. A recent Cochrane review compared LESS donor nephrectomy to traditional laparoscopy and found no

difference with regard to operative time, blood loss, complication rate, ischemia time, or graft loss. LESS demonstrated improved pain scores [26]. Ultimately, LESS technique offers a means to reduce the number of ports and improve cosmesis, but this trade-off must be balanced with the increase in the technical challenge.

Natural Orifice Transluminal Endoscopic Surgery (NOTES)

The Natural Orifice Transluminal Endoscopic Surgery (NOTES) approach, as its name implies, utilizes natural orifices (e.g., the mouth, vagina, rectum) for placement of ports or multi-channel access devices through which the surgery is performed and specimens extracted. The appeal of this technique is to access the peritoneal cavity but avoid the need for abdominal incisions. Theoretical advantages of NOTES include reduced post-operative pain, reduced incision-related complications, and improved cosmesis. Though, as with single port surgery, this approach is very technically demanding given the loss of triangulation and the inadequate instrumentation for the approach [27]. Further, the unfamiliar camera angle when approaching the kidney given the orifice access can be disorienting.

Proof of concept for NOTES nephrectomy was first reported using vaginal access in a porcine model by Gettman et al. in 2001 [28]. More recently, transvesical peritoneal access was explored, again in an animal model [29]. The first human case was reported by Kaouk et al. in 2010 [30]. In this case, dense pelvic adhesions from a prior hysterectomy required intraperitoneal port placement for introduction of the vaginal port and colonic retraction. All subsequent reports, comprising multiple single patient reports and small series) have utilized a combination of NOTES and traditional laparoscopy [31–34]. To our knowledge, there are no comparative studies assessing the NOTES approach. As such, this approach should be undertaken only by those with significant laparoscopic experience and without known comparative efficacy to other techniques.

Current Nuances

The laparoscopic nephrectomy gained widespread popularity in the 1990's and has since been modified in a number of ways as discussed above. The most significant current consideration is the debated whether radical nephrectomy should utilize a robotic surgical system. While traditional laparoscopy is more technically challenging than robotic surgery, it is also possibly less resource-intensive. However, this comparison is very complex depending on the clinical environment and outside the scope of this chapter.

There continue to be technological advances in the field of laparoscopy. The FlexDex platform (FlexDex Surgical, Brighton, MI) is a mechanical laparoscopic instrument that translates the surgeon's hand, wrist and arm movements into

corresponding movements inside the patient. This device confers the benefits of wrist movements and multiple degrees of freedom without the cost and complexity of a surgical robot [35]. Advances in endoscopic camera systems including stereoscopic three-dimensional imaging, 4 K-high definition, and near-infrared imaging, as well as flexible tip endoscopes continue to improve visualization. The advent of newer electrosurgical technology including ultrasonic shears, electrothermical bipolar vessel sealing, and thermal tissue fusion have improved hemostasis and dissection. Laparoscopic suturing devices (e.g. *Endo Stitch*™, Medtronic Minimally Invasive Therapies, *Suture Assistant*, Ethicon, and *OverStitch*®,Apollo Endosurgery Inc) have also reduced the technical challenge of suturing laparoscopically [36].

All of these technological advances continue to make non-robotic laparoscopy safer and less technically challenging. Laparoscopic skills remain a critical component in the modern urologist's armamentarium.

Key Points

Technique	Basics	Advantages	Disadvantages
Transperitoneal laparoscopy	• Most widely utilized • Trans-abdominal access and pneumoperitoneum is established • 3–5 ports are placed	• Common operation most urologists are comfortable with • Minimal additional costs and required equipment	• Still technically challenging
Retroperitoneal laparoscopy	• Completely extra-peritoneal • Retroperitoneum is dissected and insufflated	• Avoids abdominal cavity (and any adhesions that may be present)	• Less familiar approach for many • Less working space • Subtle anatomical landmarks • Difficult to maintain insufflation
Hand-assisted laparoscopy	• Utilizes device to place the non- dominant hand intra-abdominal while maintaining pneumoperitoneum • Combines benefits of open surgery (tactile feedback, manual dissection) with laparoscopy	• Technically easier • Allows less experience surgeon to deal with larger tumors or greater case complexity • Allows easier control of a hilar injury	• Larger incision • Worse cosmesis • Specialized equipment needed
Laparoendoscopic single-site surgery (LESS)	• All laparoscopic ports enter through one incision • Incision is typically peri-umbilical	• Excellent cosmesis	• More technically challenging • Specialized equipment required • Loss of triangulation

Technique	Basics	Advantages	Disadvantages
Natural orifice transluminal endoscopic surgery (NOTES)	• Abdominal access obtained via natural orifice (typically trans-vaginally)	• No scars or abdominal port sites	• Disorientating anatomy • Minimal working space • Loss of triangulation

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