Laparoscopic Nephrectomy: Present State and Future Developments

DENIS C. O'SULLIVAN, F.R.C.S.I., M.CH., FELLOW
PETER SCHULAM, M.D., PH.D., RESIDENT
LOUIS R. KAVOUSSI, M.D., CHIEF

DEPARTMENT OF UROLOGY
BRADY UROLOGICAL INSTITUTE, BAYVIEW MEDICAL CENTER
JOHNS HOPKINS MEDICAL INSTITUTIONS
BALTIMORE, MARYLAND

Laparoscopy has been a valuable tool in gynecologic practice for many years but it is only recently that this technology has been applied to urological surgery.[1] Initially laparoscopy was used in urology only for diagnostic purposes; however, following the success of laparoscopic cholecystectomy,[2] the technique was utilized to perform therapeutic procedures such as varicocelectomy and pelvic lymphadenectomy.[3,4] Open surgery has been the standard for nephrectomy for over 100 years and the techniques, results, and complications have been well documented in surgical texts. Laparoscopic nephrectomy is also a relatively new application, having only been first described in 1991.[5] This article will review the current status of laparoscopic nephrectomy and speculate on its future role. The pros and cons of the laparoscopic technique when compared to open nephrectomy will also be discussed.

PRESENT STATE

Since Clayman et al. first described the technique of laparoscopic nephrectomy in 1991,[5] many clinical and experimental reports have been published worldwide.[6-49] Nevertheless, the total number of published cases is still relatively low with most reports containing fewer than 15 patients and only a few centers with a greater experience.[6-45] These reports reveal a great variability in trocar placement, surgical approach, and equipment used, indicating that laparoscopic nephrectomy is still in the stage of development and evolution.

The first laparoscopic nephrectomy was performed in an 85-year-old woman with a renal tumor.[5] Since then, all types of renal pathology requiring nephrectomy have been managed laparoscopically. Surgical techniques employed in laparoscopic nephrectomy have been developed and applied successfully to partial nephrectomy,[7,16,50] nephroureterectomy,[30-32] and live donor nephrectomy.[11,51] The only renal disease that has repeatedly caused laparoscopic failure is xanthogranulomatous pyelonephritis in which surrounding structures become involved with a dense fibrotic process. This does not allow dissection through tissue planes and increases the risk of bleeding. In addition, large renal tumors (>10 cm) and tumors with venous tumor thrombi have not been removed due to limitations in manipulation, organ entrapment, and laparoscopic vascular reconstructive techniques.

TECHNIQUE

The technique of laparoscopic nephrectomy has undergone many changes since it was first introduced in 1991.[5] The initial description included a three-stage patient preparation which began with cystoscopy

and insertion of a ureteric stent and wire. Following this, the patient was laid flat and the initial access obtained. Finally the patient was manually repositioned in the lateral decubitus and the nephrectomy performed. Repositioning can be eliminated by placing the patient in the lateral position from the beginning of the operation[12,34,38] and the stent can then be inserted, with the patient in this position, using a flexible cystoscope.

The function of the stent is to aid in identifying the ureter and this is done by observing movement when the external part of the stent and wire is moved.[5,7,10,12,16,24,39] It is necessary to have had the ureter dissected relatively free for this technique to be of value. An alternative to this maneuver has been the illuminated stent which lights up the course of the ureter.[52] Early in a surgeon's experience, the combination of rigidity, movement, and illumination greatly enhances the positive identification of the ureter. Some surgeons have gradually abandoned these techniques as their experience with the procedure and knowledge of laparoscopic anatomy has increased.[12,13,20,38] The approach to each kidney is modified depending on the disease process present in each patient. Avoiding cystoscopy, stent insertion, and repositioning of the patient has resulted in reduced complexity and overall operative time of laparoscopic nephrectomy.[12,20,38]

In the earlier cases preoperative embolization with vascular coils was often used[5,24,39] but this has been largely discontinued because no particular advantage has been demonstrated and it subjects the patient to an additional procedure.

Traditionally, the Veress needle was inserted at or below the umbilicus with the patient in the supine position.[5,32,33,37,39,43] This is considered to be the optimal place in which to insert the needle because the peritoneum is attached to the posterior rectus sheath, so the risk of extraperitoneal insufflation is reduced. If the patient is being insufflated in the lateral decubitus position, it can be difficult to insert the Veress needle at the umbilicus especially in obese patients. It can also be difficult to identify any injuries caused by the needle, as the bowel lies up against the abdominal wall at the level of the umbilicus when the patient is in the lateral position. Because of these factors, the Veress needle should be placed laterally, (i.e., between the lateral edge of the rectus and the anterior axillary line). Some surgeons use an open technique (Hasson) for insertion of the first port because there is less risk of visceral damage and fewer problems with abdominal wall insufflation.[7,12,20,38] The open technique of trocar placement is also recommended if there has been previous abdominal surgery because of the possible risk of perforating bowel with the needle or trocar.

Most surgeons use five ports as described in the original report[5,14,15,20,28,32,37,43]; however, some authors use only three ports, particularly in children.[7,10,13] The camera is usually inserted in an anterior port initially for dissection of the anterior surface of the kidney. When operating on large kidneys, where it can be difficult to do all of the dissection from one perspective, it can be very useful to reposition the camera in the posterior port and for the surgeon to move to the opposite side of the table when mobilizing the posterior part of the kidney and vessels.

The approach to the kidney has also been modified by many surgeons from the original description of transperitoneal colonic mobilization.[5] In slim patients with smaller kidneys, the kidney can be removed by dissecting directly through the colonic mesentery.[19,20] This method is more difficult when the patient is obese or the kidney is large, as there is the possibility of damaging the mesenteric blood supply.

In order to reduce the morbidity of a transperitoneal nephrectomy, the retroperitoneal approach has been assessed in both animal and human studies.[10,11,16,17,21-23,26,27,34,51,54] To insufflate the retroperitoneal space, the Veress needle can be inserted safely 2 cm above the iliac crest in the posterior axillary line and angled 10 degrees anteriorly.[34] Alternatively, some surgeons make a small incision and use blunt finger dissection to develop a cavity to place the ports in the retroperitoneal space.[10,12,41] Gaur introduced the idea of balloon dissection of the retroperitoneum following the initial dissection.[41] In this technique, a finger of a latex glove attached to a catheter or a commercially available balloon is inserted into the retroperitoneum. The balloon is inflated to 600 to 1000 mL with saline and left in place for 5 minutes to allow hemostasis. The balloon creates a working space and bluntly mobilizes part of the kidney.[7,10,16] Further dissection is then done under direct vision. Smaller balloons can be placed into the tissue planes for further dissection.

The retroperitoneal approach has been used for 70 nephrectomies in published series.[10,11,16,17,21-23,26,27,34,41] It is not the most popular approach; however, because the transabdominal method was first to gain prominence, the working space is smaller and anatomical landmarks are fewer. The lateral retroperitoneal approach has the possible advantage of reducing the complications of bowel injury and adhesions,[7,9,10,16,23,34,54,82] but there have been no direct comparisons between transperitoneal and extraperitoneal nephrectomy.[9] The retroperitoneal approach may be advantageous in patients who have had previous abdominal surgery. It is also useful when exposure of only a portion of the kidney is required such as in renal biopsy and cyst excision. Carbon dioxide absorption has been reported to be less from retroperitoneal insufflation than from a pneumoperitoneum. This may be advantagous in patients with respiratory disease and ventilatory problems, but this must be balanced against the increased chance of mediastinal emphysema.[55]

The direct posterior approach has been studied in animals. It provides better access to the kidney and adrenal by providing a larger working space than the lateral retroperitoneal approach, as the intra-abdominal organs fall further forward.[46,47] In a porcine model, gasless nephrectomy has been performed by this approach, thus avoiding the problems associated with gas insufflation.[56]

In the initial case, Clayman et al. occluded each of the segmental renal arteries and veins separately with five vessel clips.[5] The current practice of most surgeons is to use three proximal and two distal clips on the main artery and the main renal vein to achieve hemostasis.[25,39] The newer right-angled stapler has also made clip application easier, as it enables the surgeon to see the ends of the staple before application. This reduces the risk of entrapment of adjacent structures and also overcomes concerns that a vessel may not be completely occluded. Some surgeons tie ligatures around the vessels, but this takes more skill and time.[20] The vein is usually larger than the artery and can more easily be occluded and cut in one action with the endovascular stapler.[12,21,31] This instrument inserts six lines of staples on the vessel and then cuts between rows three and four. The efficacy and safety of this approach has been confirmed in animal studies.[53]

Once excised, the kidney is usually maneuvered into a small sac placed into the abdomen via one of the ports. The sac is then drawn out through a 10-mm port site, and the kidney is broken up by a

morcellator (Cook, Spencer, Ind.)[5,25] or a pair of sponge forceps.[20,32,39] There is concern about using this technique when treating malignancy, as there is potential for sacs to leak fluid after renal morcellation[57] and thus spread tumor cells into the peritoneal cavity and wound. Port-site tumor seeding has been reported following laparoscopic treatment of ovarian tumors[58] and after bladder tumor biopsy,[59] although none has been reported with renal tumors. There are studies, however, that demonstrate advantages to laparoscopy for malignancy. Clinical research has shown that immunity is less impaired following laparoscopy when compared to open surgery.[60] In addition, an in vivo study has shown that tumor growth rate is less after laparoscopy compared with open surgery.[61] Thus, these studies imply that laparoscopy may be advantagous when approaching a malignant process if complete tumor excision can be ensured.

Another concern with morcellation of tumors is that staging of the tumor is difficult, as capsular and fat invasion cannot be assessed accurately. However, current treatment is not altered in the event of invasion being found.

Some surgeons now make a small lower midline (6-cm) incision which is just large enough to remove the kidney intact.[15,24-26,39,48] This incision is less painful and less disfiguring than conventional nephrectomy incisions, especially for large tumors and obese patients. In retroperitoneal cases, a short oblique incision is made in the flank. In certain situations, the kidney can also be delivered through the vagina.[29] These adaptations allow for removal of the intact organ, thereby lessening the likelihood of tumor seeding, and provide a better pathological specimen.

COMPLICATIONS

Overall complication rates reported for laparoscopic nephrectomy are 15% to 20%,[33,36,39,42,45] which are similar to those of open nephrectomy.[25] Conversion to open operation (4% to 15%) is usually due to uncontrolled hemorrhage or inability to complete the surgery.[36,37,39,43,45] The conversion rate decreases with experience.[33,45]

The complications specifically related to laparoscopic surgery can be prevented with proper attention to detail.[39] Firstly, patient positioning must be done with care to avoid pressure injuries to nerves and skin during the procedure. Moreover, injuries to vessels and bowel caused by Veress needle and trocar placement should be minimized by cautious insertion under direct vision. Care must be taken with fluid replacement during laparoscopy. Fluid overload can occur during laparoscopy if fluid replacement is given at the same rate as during an open procedure where insensible fluid loss is much greater. Vascular injuries can be difficult to treat endoscopically because of limited access and loss of illumination due to light absorption by blood. To avoid bleeding, vascular structures should be isolated delicately and each vessel individually ligated. The surgeon must inspect the operative field under low pressure to identify previously unrecognized bleeding. The trocar sites should be inspected to check for abdominal wall bleeding and all 10-mm or greater port sites should be closed under vision to prevent herniation. Significant postoperative pain should suggest to the surgeon that an intra-abdominal organ may have been injured inadvertently and require treatment.

LEARNING CURVE

A significant learning curve has been reported by all authors who have performed laparoscopic nephrectomy.[39,43] Authors comment that it takes anywhere from 10 to 20 nephrectomies to achieve some comfort with the procedure.[36,39,43] If a surgeon is going to perform laparoscopic surgery, he or she has to be competent at the open techniques as well. It is important that the learning process start by studying in dry labs on pelvic trainers and then moving on to animal surgery before attempting clinical applications.[40,49] It is important to attend accredited courses and, until the surgeon becomes proficient, it is essential to have an assistant who is already experienced in laparoscopic surgery.[62] Any new procedures which are developed should initially be evaluated in an animal model to assess its feasibility and identify the most appropriate techniques.[46,47,50,51,53,61]

TECHNICAL AND EQUIPMENT IMPROVEMENTS

There have been a number of advances in equipment since the first nephrectomy was performed. The right-angled stapler, as previously mentioned, facilitates vascular occlusion. The endovascular GIA stapler, which is used for occluding the renal vein, can also be used for partial nephrectomy where it can staple and cut along the junction of healthy and diseased tissue. The argon beam coagulator, although not used in total nephrectomy, is useful to stop bleeding from raw surfaces during partial nephrectomy and renal biopsies carried out by the laparoscopic method.[7,16]

Flexible ultrasonic and Doppler probes may be useful to help locate the main renal vessels and ureter as well as to identify segmental vessels during a partial nephrectomy.[63,64] The high frequency (7.5 to 10 MHz) of the ultrasonic probes gives good definition of adjacent structures. Gastrointestinal surgeons have found laparoscopic ultrasound to be effective when assessing the biliary tract.[67] In gastrointestinal and pancreatic tumors, endosonography has been shown to improve staging and alter clinical management in up to 60% of cases.[68-73] Intraoperative ultrasound has not been used extensively in urology except in varicocelectomy,[65] and occasionally in nephrolithotomy,[7,66] because of the combination of cost, the limited indications, and the surgeons' inexperience with the technique.

Closure of the fascia through the trocar site can be challenging. Port site closure to prevent herniation has been made easier with devices such as the grasping needle (Inlet, Eden Prairie, Minn.) or hook (Cook, Spencer, Ind.), which can insert and withdraw the suture through the full thickness of the abdominal wall.

The combined Seitzinger bipolar, grasping, coagulating, and cutting forceps is useful for dividing tissue layers with many small vessels and may be helpful around the upper pole of the kidney and the adrenal. Combined suction, irrigating, and diathermy instruments (Cook, Spencer, Ind.; Circon, Stamford, Conn.; Stryker, San Jose, Calif.) have been advocated to help to reduce the frequency of instrument changes during surgery.

Fogging of the endoscope is especially troubling and can occur at any time during the procedure. This leads to difficulty carrying out dissection and can be dangerous if it happens at a particularly important part of the operation, such as when dissecting the renal vessels. This problem can be reduced by heating the scope in water bath before insertion, but this does not overcome any fogging beyond the early part of the operation. Therefore, the surgeon has to remove the endoscope for cleaning, sometimes repeatedly, which may entice the surgeon to operate at times with a suboptimal view. Attaching the CO_2 gas to a port other than the one with the laparoscope and heating the cold CO_2 gas before it reaches the abdomen can reduce

the amount of fogging that occurs.[74] The problem may also be reduced by using a heated self-washing laparoscope (Circon, Stamford, Conn.).

The 3-D laparoscope (Wolf, Vernon Hills, Ill.) has the capability to overcome one of the major drawbacks of laparoscopic surgery, which is the difficulty with depth perception.[22,75] Lack of 3-D vision is not such a major drawback in excisional surgery such as nephrectomy, although it may slow the dissection. The main benefit of using the 3-D endoscope is its ability to help when performing detailed work, such as hilar dissection or reconstructive surgery. Flexible and semiflexible laparoscopes have not gained popularity as yet, but they can be useful to reach difficult areas and may also allow a more thorough examination than the rigid endoscope.[76]

Automatic suturing devices (U.S. Surgical, Norwalk, Conn.) make endoscopic suturing easier and quicker than when using a needle holder and free needle. They are mainly beneficial in reconstructive procedures such as pyeloplasty but may also be of use, to experienced users, during nephrectomy in the event of a vascular injury. Suturing has been made even easier with the introduction of the reabsorbable suture clips (Ethicon Endo-Surgery, Cincinnati, Ohio), which remove the need for endoscopic knot tying.

Robotic and semi-robotic arms to hold and move the endoscope are also a major advance in laparoscopic surgery. When compared to a human assistant, they hold position much more accurately, without shake or drift.[77] As a result, the surgeon can focus on the required image without having to relay the message repeatedly to an assistant who in turn may have difficulty interpreting the commands. The fully robotic arms (Computer Motion, Goleta, Calif.) are more effective because, once attached, the endoscope does not have to be handled during the operation.[77,78] They are, however, more expensive than semi-robotic or rigid arms that are manually repositioned when needed.

COMPARISON WITH THE OPEN TECHNIQUE

Laparoscopic nephrectomy is still a relatively new procedure and operative techniques have to be refined and standardized. It has several benefits and disadvantages when compared to open surgery. At present, studies have demonstrated that open nephrectomy has a lower hospital cost than laparoscopic nephrectomy,[12,36,37] except in one pediatric study in which laparoscopy was cheaper.[8] The greater expense is primarily due to the costs of the disposable equipment and the longer operating time. While the operating time is longer, it should be noted that recent operative times have been reduced significantly when compared with the initial series.[5,7,11,13,24,36,38,39] In a recent report, the time required for the laparoscopic approach was similar to that required for open cases.[12] In children, where the disease process is usually benign, it is often possible to do a rapid open nephrectomy through a cosmetically acceptable incision.[81] New developments and additional equipment such as ultrasonic probes and robots will mean that laparoscopic surgery will tend to have a higher equipment cost. Robots may in turn reduce the long-term costs by reducing the number of personnel needed at an operation.[78] These considerations have to be balanced against the advantages of laparoscopy over open surgery. The benefits of less pain postoperatively, a shorter in-hospital stay, better cosmestic result, and a shorter time to full recovery have been verified at many sites.[5,7,12,36-39] The incidence of incisional hernia and cutaneous nerve damage is minimal with laparoscopy, and the occurrence of a bulge from muscle paralysis, which is relatively common with the open flank incision, is rare. The added social and economic benefits of reduced time away from work and reduced convalescent care in these patients are as yet an undetermined advantage of laparoscopic nephrectomy.

THE FUTURE

Laparoscopic nephrectomy has gained its place in the urologist's armamentarium as an alternative to treat renal pathology. As more urologists become practiced in laparoscopic surgery, applications and indications will be expanded. More controlled methods of organ entrapment and tissue removal need to be developed. Laparoscopic nephrectomy in patients with malignancy needs further study and improvement especially if one is going to be able to deal with large tumors, lymphadenopathy, and those with vein involvement.[45]

Technological advances will gradually make the operation easier and quicker to perform, as has already occurred in the past 5 years. Robotic assistants should make the operation safer because of consistent and accurate performance.[77] Indeed, robots have the potential to be more gentle and have better tissue-handling capabilities than an assistant. Eventually the operation may be performed by robots with the procedure being dictated by preset limits determined from preoperative investigations, or by the surgeon monitoring the procedure, using a combination of intra-abdominal video, ultrasonic, and magnetic resonance scans. Alternatively the surgeon may operate on a "virtual" patient using tactile and positional information gathered from sensors in the robotic arms which are actually doing the operation at the same time in the patient.[79,80] Advances in telemedicine will enable expert surgeons to teach and help less experienced surgeons at local or even remote sites.[77]

Laparoscopic surgery is a new approach in urology but, as with open surgery at present, future developments will replace it with less invasive options. Then discussions will concern whether the new techniques can improve upon the results of laparoscopy. In the wave of technological advances that have been made, we must never lose sight of our goal which is to continually improve the standard of patient care. **STI**

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