Laparoscopic renal surgery

While principles of laparoscopic surgery have been used by gynecologists for several decades, it was not until recently that those techniques have had an impact on the surgical management of renal diseases. Witnessing the rapid replacement of open surgical removal of the gallbladder by laparoscopic cholecystectomy [1, 2], urologic surgeons have now focused their attention on employing laparoscopic techniques in their approach to surgery of the kidney.

An important step forward in the development of laparoscopic renal surgery was the development of a solid organ entrapment system (Lapsac, Cook Urology, Inc. Spencer, Indiana, USA) and a high-speed electrical tissue morcellator (Cook OB/GYN/Cook Urology) to fragment and evacuate tissue from the abdomen [3]. With this equipment the laparoscopic removal of a kidney was first accomplished on June 25, 1990 at Barnes Hospital, Washington University School of Medicine; this procedure has been successfully performed subsequently at various medical centers throughout the world [4—22]. In addition other applications of laparoscopy to renal surgery have recently been reported: nephroureterectomy, renal cyst decortication, renal biopsy, nephropexy, partial nephrectomy and repair of the obstructed ureteropelvic junction. In addition, the laparoscope has also been used to aid in the placement of a peritoneal dialysis catheter, and to perform intraabdominal marsupialization of a postrenal transplantation lymphocele. Currently under investigation is a further extension of laparoscopic techniques into the area of donor nephrectomy.

Overall, the majority of these procedures are of an ablative nature (such as nephrectomy, nephroureterectomy, partial nephrectomy, renal cyst excision, etc.). However, of significance is the more recent development of laparoscopic reconstructive techniques in which the surgeon applies suturing skills through the laparoscope to correct an underlying renal abnormality. This type of work greatly broadens the potential range of laparoscopic renal surgery to the point that it may eventually encompass almost all aspects of renal surgery.

Laparoscopy: A technical overview

Laparoscopic surgery is performed through the gas-filled abdomen or retroperitoneum with the patient under general anesthesia or intravenous sedation. The gas, usually CO₂, is instilled into the abdomen via a 14 gauge needle with a blunt retractable tip (Veress needle) which is blindly passed into the abdominal or retroperitoneal cavity. Approximately 4 to 7 liters of CO₂ are instilled; when the intraperitoneal (pneumoperitoneum) or retroperitoneal (that is, pneumoretroperitoneum) pressure reaches 15 mm Hg, the inflow of CO₂ is halted. At this point, a sharp 10 or 12 mm trocar with a protective retractor plastic shield is blindly passed into the gas-filled abdomen or retroperitoneum; in the former circumstance the site of entry is most commonly the umbilicus. The obturator of the trocar is removed, leaving behind the 10 or 12 mm sheath. The sheath has a flap valve to prevent the escape of gas from the abdomen. The gas line is connected to the sheath to maintain the pneumoperitoneum or pneumoretroperitoneum. A 10 mm endoscope, attached to a camera, is passed through the sheath and the peritoneal or retroperitoneal contents are examined. The image is displayed on a television monitor for all to view (Fig. 1).

In the case of a pneumoretroperitoneum, additional working space can be obtained by inserting a balloon-bearing catheter through the sheath and inflating the balloon with 1 to 2 liters of saline. When the balloon is deflated and removed, much of the retroperitoneal fat will have been displaced thereby facilitating identification of the retroperitoneal structures.

Dependent upon the planned procedure, upwards of five additional trocars may be placed under endoscopic control; these range in size from 5 mm to 15 mm and are used for the passage of a variety of laparoscopic instruments (such as scissors, tissue staplers, entrapment sacks, graspers, biopsy forceps, electrosurgical probes, morcellators, etc). At the conclusion of the procedure, the sheaths are removed, the CO₂ is allowed to escape from the abdomen and the skin sites are sewn or taped closed (for the ≥10 mm sheaths, the fascia is sewn closed too). Most patients are able to aliment and ambulate the same day as the procedure; hospital discharge is on the same day for minor procedures (such as lymphocelectomy) or within three to four days after a major procedure (such as nephrectomy).

Laparoscopic renal surgery: Recognized procedures

Laparoscopic nephrectomy

During the past two and a half years, laparoscopic nephrectomy for benign disease of the kidney has been gaining worldwide acceptance. Presently, more than 100 laparoscopic nephrectomies have been performed worldwide. Indications for laparoscopic nephrectomy have mirrored the surgical indications to remove a benign kidney, regardless of the underlying pathology. Accordingly, laparoscopic nephrectomy has been performed successfully in patients with: acquired cystic disease of the kidney, renal hypertension, chronic pyelonephritis and renal dysfunction, xanthogranulomatous pyelonephritis, and renal atrophy associated with flank pain (such as reflux nephropathy or ureteropelvic junction obstruction).

Laparoscopic nephrectomy is performed through five ports. The approach can be either abdominal or retroperitoneal; the kidney is either morcellated in an entrapment sack (such as benign disease) or removed intact within the entrapment sack.

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via a 5 to 7 cm suprapubic or flank incision (such as malignant disease) [4–18].

An in depth study of laparoscopic nephrectomy for benign disease was recently completed at our institution: 20 patients undergoing laparoscopic nephrectomy were compared with 23 patients undergoing surgical nephrectomy for benign disease [8]. The patient groups were similar with regard to age (44 years vs. 56 years) and operative risks. Laparoscopic nephrectomy was successfully completed in all but 1 patient (95% success rate). The mean operative time for the laparoscopic nephrectomy (355 min) was significantly longer than the time to complete an open nephrectomy (165 min). However, the laparoscopic patients required less postoperative pain medication (54 mg vs. 123 mg), had a shorter hospital stay (3.7 days vs. 7.4 days), returned to work sooner (1 month vs. 2.5 months), and had a significantly more rapid 100% convalescence (1.8 months vs. 9.9 months).

In contrast to laparoscopic nephrectomy for benign disease, the application of laparoscopic nephrectomy to malignant disease is controversial. One of the major concerns is the possibility of tumor spread at the time of tissue morcelation and organ retrieval. To minimize this problem, we have recently begun to deliver the kidney intact within the entrapment sack via a small (that is, 5 to 7 cm) midline suprapubic or muscle-splitting flank incision.

To date, only a handful of laparoscopic nephrectomies for renal cell cancer have been performed. Kavoussi (unpublished data) recently reviewed eight patients undergoing total (kidney, perirenal and pararenal fat) or radical (that is, kidney, Gerota’s fascia and the ipsilateral adrenal gland) laparoscopic nephrectomy for renal tumors ≤ 6 cm in size. The average operating time was lengthy (7 h); however, these patients left the hospital in four days, returned to their usual activities in two weeks, and were fully convalesced in four weeks. This is a marked improvement over surgical radical nephrectomy in which the hospital stay (7.1 days), return to work (7.5 weeks), and complete convalescence (5.25 months) are significantly longer (Kavoussi: unpublished data).

Laparoscopic nephroureterectomy (NU)

The first laparoscopic nephroureterectomy was performed at Washington University School of Medicine, Barnes Hospital, in May of 1991 [20]. Since that time, numerous other urologists have successfully removed the kidney and ureter laparoscopically. The principal indication for laparoscopic NU is transitional cell cancer affecting the upper urinary tract.

Laparoscopic NU is performed through six ports. The additional port is placed suprapublically and allows the surgeon to pass a stapling device which can simultaneously staple and incise a 3 cm cuff of the bladder [22]. Three rows of staples remain on the bladder cuff and the bladder proper. Because of the underlying malignant lesion, the kidney and ureter, after being placed into the 5×8 inch entrapment sack, are delivered intact via a 5 to 7 cm midline suprapubic or flank incision.
In a recent analysis of our initial series of laparoscopic nephroureterectomies performed for transitional cell cancer of the upper urinary tract, mean operative time among six patients was 7.29 hours and estimated blood loss averaged 180 cc [21]. There were no intraoperative complications or transfusions; however there was one major postoperative complication. A high risk patient (ASA IV) developed postoperative bleeding and was surgically explored. A small vein emanating from the inferior border of the right adrenal gland, was fulgurated. Postoperatively, he developed adult respiratory distress syndrome (ARDS) and recurrent cardiac dysrhythmias; he expired, in the hospital, on postoperative day 66.

Charts of the last eight consecutive patients who underwent a surgical nephroureterectomy for upper tract transitional cell cancer at our institution were reviewed and compared with our laparoscopic nephroureterectomy series (6 patients). The laparoscopic approach resulted in significantly longer operating room times (7.29 hr vs. 3.37 hr). However, the laparoscopy patients had a sixfold less requirement for parenteral analgesics (24 mg of MS equivalents vs. 149 mg) and were discharged from the hospital in half the time (4.6 days vs. 9.25 days) [21]. Also, after hospital discharge, the laparoscopic patients used five times less oral analgesics. Convalescence for the laparoscopic patients was rapid: return to work or usual activities times less oral analgesics. Convalescence for the laparoscopic patients was rapid: return to work or usual activities within one week [23, 24]. To date, no complications have occurred in half the time (2.6 weeks vs. 6 weeks), and full recovery was five times quicker (5 weeks vs. 7.4 months) [21].

**Laparoscopic renal cyst excision**

Most renal cysts are asymptomatic. However, when a renal cyst produces flank pain, obstruction, or renin mediated hypertension, cyst aspiration and sclerosis or cyst excision is usually the next step.

Laparoscopic renal cyst excision is performed through four ports. The approach can be transabdominal or retroperitoneal. The peripheral portion of the cyst is excised. The base of the cyst can be biopsied and then electrocoagulated.

Small clinical series (4 patients or less) have been reported on laparoscopic decortication of symptomatic renal cysts [23–25]. The size of the cysts treated have varied from 6 to 20 cm [23, 24]. Mean operative time was 121 minutes (range 50 min to 3 hr) with a mean intraoperative blood loss of 50 cc [23]. All patients were discharged on postoperative day one [23] and returned to their usual activities within one week [23, 24]. To date, no symptomatic or radiographic recurrence has occurred during the three to seven month follow-up period [23].

The laparoscopic approach to the symptomatic renal cyst must be carefully contrasted with the even less invasive technique of percutaneous cyst aspiration and ethanol sclerosis which has a > 90% total success rate [26]. Also, a direct percutaneous approach to the symptomatic renal cyst is likely less morbid than the laparoscopic treatment.

**Laparoscopic renal biopsy**

In 1991, Squadrito and Coletta introduced a method of laparoscopic renal exploration and biopsy using a four port approach [27]. As outlined by the authors, this approach could be of value in patients with relative or absolute contraindications to percutaneous biopsy (that is, severe uncontrolled hypertension, hemorrhagic diathesis, solitary/ectopic or horse-shoe kidneys) [27].

**Laparoscopic surgery: Ancillary procedures**

**Laparoscopic drainage of post-transplant lymphoceles**

In the renal transplant patient, the risk of lymphocele formation ranges from 0.6% to 18% [28]. In these high risk patients, a minimally invasive approach is commendable albeit often ineffective. Needle aspiration, external drainage, or percutaneous sclerotherapy have been associated with high recurrence rates [29, 30]. In contrast, open surgical exploration and marsupialization, while effective, result in significant postoperative discomfort, an average hospital stay of three to five days and prolonged convalescence [31]. Accordingly, laparoscopic transabdominal internal marsupialization is an appealing alternative, which combines the virtues of a minimally invasive approach (short hospital stay, reduced postoperative discomfort and rapid convalescence) with an effective therapeutic modality.

Laparoscopic drainage of a post-transplant lymphocele was first reported by McCullough and co-workers in 1991 [31]. In their case, marsupialization via three ports was achieved by a transabdominal approach. An 8 x 2 cm segment of the lymphocele wall was excised and the inferior free edge of the omentum was drawn into the cavity and secured with titanium clips. Operative time was 90 minutes with an estimated blood loss of less than 60 ml; the patient was discharged on postoperative day one. Follow-up CT scan performed seven weeks later revealed complete resolution of the lymphocele. Subsequently, other surgeons have reported on their successful experience with laparoscopic drainage of a post-transplant lymphocele [32–34].

**Laparoscopic placement of a chronic ambulatory peritoneal dialysis (CAPD) catheter**

While sequential inspection of the abdominal cavity (that is, peritoneoscopy) followed by nonendoscopic placement of a CAPD catheter has been reported more than 10 years ago, modern day laparoscopy offers the physician the ability to place a CAPD catheter under direct and continuous optical control [35, 36]. In patients with a history of prior extensive, multiple or complicated intra-abdominal procedures, intraperitoneal adhesions may greatly complicate the placement of a CAPD catheter. Recently, Albala and Kinzler described a laparoscopic technique of placement of a CAPD catheter in a pediatric patient [37]. As stated by the authors, this approach might be of potential benefit to other patients with previous intra-abdominal operations who require placement of a CAPD catheter [38]. Being able to perform an adhesiolysis and then visually confirm proper catheter placement is a significant advantage of the laparoscopic approach.

**Laparoscopic renal surgery: Case reports**

**Laparoscopic partial nephrectomy**

The technique for performing a laparoscopic partial nephrectomy was developed and tested in the animal laboratory at Washington University School of Medicine [38]. This method required the placement of five ports and the use of two new pieces of equipment: a laparoscopic tourniquet for holding and compressing the designated site of the renal incision and an argon beam coagulator to effectively seal and coagulate the cut parenchymal surface.
Subsequently, Winfield et al performed the first clinical partial nephrectomy in a 31-year-old woman with a scarred, chronically infected, calculus-ridden left lower pole [39]. In addition, Schuessler (personal communication) and we have used this approach to perform a wedge excision of a small (3 cm and 1 cm) renal cell cancer and an oncocytoma, respectively. The operative time in these two patients was three and five hours; there have been no complications. The hospital stay has been brief (<5 days) and recovery has been rapid (<3 weeks).

Laparoscopic nephropexy

Albeit a rarely seen condition, the ptotic kidney can be a source of significant, chronic flank discomfort. The diagnosis of this condition rests on several features: recurrent flank pain which can be partially or totally relieved when the patient is recumbent, documentation of a downward displacement of the kidney of more than two vertebral bodies (> 5 cm) when the patient moves from a supine to an erect position, and a palpable pelvic mass when the patient is erect. Often hydronephrosis or obstruction can be documented on intravenous urography or a renal scan when the patient moves from the supine to the erect position.

Classically, the kidney is approached through a flank incision and sutures are placed through the renal capsule and into the underlying psoas or quadratus lumborum muscle. Recently, a transabdominal and transretroperitoneal laparoscopic approach was used respectively in a 25-year-old and 48-year-old woman with symptomatic ptosis. Both patients met the aforesaid criteria and had a longstanding complaint of chronic flank discomfort (>1 year). In the first patient a four port transabdominal approach was used, and the medial edge of the anterior leaflet of Gerota's fascia was brought beneath the lower pole of the kidney and affixed to the incised lateral edge of the peritoneal reflection with tacking staples. In the second patient, a four port retroperitoneal approach was used and the kidney was affixed to the quadratus lumborum with five silk sutures. The operative time was five hours and 3.3 hours, respectively; hospital discharge was on postoperative days 2 and 3. In both patients, their pain has been relieved and the kidney has remained fixed in the retroperitoneum. Both patients returned to work in less than three weeks.

Pyeloplasty

The obstructed ureteropelvic junction has classically been corrected via an open surgical approach. Usually, the point of obstruction is completely excised and the enlarged renal pelvis is surgically tapered. The proximal ureter is then anastomosed to the tapered renal pelvis.

Recently, using a five port, transabdominal approach, Schuessler, Preminger, and colleagues were able to complete a sutured laparoscopic pyeloplasty in four adult patients [40]. The operative time ranged from three to seven hours; the average postoperative hospital stay was three days. This is the first report of major reconstructive renal surgery being performed laparoscopically.

Laparoscopic renal surgery: Laboratory studies

Laparoscopic live-donor nephrectomy

Live-donor nephrectomy, while providing the recipient with the best chance of a long-term functional transplant, leaves the donor markedly, albeit temporarily, impaired. Indeed, in a recent review of healthy young patients undergoing standard surgical donor nephrectomy via a flank incision the hospital stay was 5.6 days, and 75 mg of morphine sulfate were needed for postoperative pain relief. These patients did not return to their routine activities for 2.3 months and were not fully recovered until 9.5 months postoperatively [8].

Given our sanguine experience with laparoscopic nephrectomy for benign and malignant renal disease, we elected to study whether similar techniques could be applied to harvesting a donor kidney [41]. In order to perform this with a six port, transabdominal approach, two problems had to be overcome: a method for rapid delivery of the kidney via a 5 cm lower midline abdominal incision and a technique for safely cannulating the renal artery in order to rapidly cool the kidney. The first problem was resolved with a 5 mm double-sling apparatus. With this apparatus, the kidney, once freed, could be removed from the abdomen in 155 seconds. The second problem was answered by development of a 7F curved tip end hole angiographic catheter with a 15 mm (maximum diameter when inflated) balloon affixed to its tip. With this device the kidney could be cooled to 13.3°C within five minutes of interrupting renal arterial blood flow. The renal core temperature upon delivery of the kidney from the abdomen was 15°C.

Once these two techniques were developed, a formal animal study was completed. Three weeks after a laparoscopic right nephrectomy, 15 pigs were divided into two groups: the study group (10 pigs) underwent a laparoscopic left live-donor nephrectomy and conventional autotransplant; the control group (5 pigs) underwent an open left live-donor left nephrectomy and conventional autotransplant. Mean warm ischemia time was 14.3 minutes (study group) and 2 minutes (control group; P = 0.02). The ureteric, renal artery, and renal vein lengths were similar between the two groups. There were no injuries from cannulation of the renal artery. In the surviving animals (6 study animals and two controls) no statistically significant difference was seen in the creatinine clearance levels 3, 7, and 30 days postoperatively.

Despite these favorable laboratory results, it is still a significant step to the clinical realm. However, if this procedure becomes clinically feasible, then the renal donor would no longer be significantly inconvenienced or pained by his voluntary act of kindness. Indeed, the day may come when the renal donor may be able to leave the hospital on the first postoperative day and return to his or her routine activities in less than a week.

Summary

Despite all the recent developments in laparoscopic renal surgery, it has to be kept in mind that although only small incisions are made, laparoscopy is still surgery. Therefore, the technical background as well as the surgeons' skills must ensure that any laparoscopic procedure can be quickly converted into an open surgical procedure, if complications (such as bleeding or injury to the viscera) or unexpected difficulties (inability to establish a pneumoperitoneum) should occur.

Also, as with any new procedure, the value of each new laparoscopic technique can only be determined by direct and critical comparison to its current open incisional surgical counterpart. In order to progress from a heralded "fad" to a
medically accepted “fixture,” each laparoscopic innovation must provide the patient with a less morbid, yet equally efficacious alternative to open surgery. Stated more simply, the query remains: “Is it new but is it better?”

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