Live Donor Nephrectomy

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Contents

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Abstract

Live donor nephrectomy, first performed in the 1950s, has gained popularity over the last 30 years as an alternative option to increase organ availability for patients awaiting renal transplant. However, until the advent of laparoscopic donor nephrectomy in the mid-1990s, much controversy persisted over the ethical nature of living donor nephrectomy with respect to donor morbidity. Despite dramatically decreased morbidity and mortality for live donors today, controversy still persists over the long-term implications of live kidney donation, with clearly demonstrated disparities in outcomes based on various demographic factors. This chapter details the history of living kidney donation, followed by the risks and specific complications unique to living kidney donation and the effects of various demographic characteristics on these complications. Finally, a detailed review of operative technique and variations is also offered.

Keywords

Living donor · Living donation · Live donor · Donor nephrectomy · Laparoscopic donor nephrectomy · Kidney transplant · Renal transplant · Nephrectomy · Kidney donation

Introduction

History and Evolution of Live Donor Nephrectomy

Joseph Murray and the First Successful Living Donor Nephrectomy

The first living donor kidney transplant in humans was performed in 1952 by a French surgeon named René Küss within a team led by nephrologist Jean Hamburger. His recipient patient was a 16-year-old boy with a solitary kidney who had suffered a traumatic injury, requiring emergent nephrectomy. He underwent renal transplant, with his mother serving as the living kidney donor. Unfortunately, the graft failed after just 3 weeks due to rejection (Legendre and Kreis 2010). Two years later, an American surgeon named Joseph Murray performed the first successful human kidney transplant in Boston. The recipient underwent live donor renal transplant from his monozygotic twin, eliminating the need for immunosuppression, for which there existed only a limited understanding at the time. The recipient lived a total of 8 years post-transplant and his graft eventually failed due to recurrent disease. Murray was awarded the Nobel Prize for Medicine in 1990 for his accomplishments (Hatzinger et al. 2016).

Progress with Deceased Donor Kidney Transplant

Following Murray's success, much of the progress over the coming years would focus on deceased donor kidney transplantation. Immunosuppressive therapies were optimized to avoid rejection in non-HLA identical patients, while minimizing potential adverse effects such as infection, overwhelming sepsis, and malignancy. With improvements in immunosuppressive techniques, the number of successful deceased donor transplants grew at a rapid pace.

Organ Shortage and Emergence of Live Kidney Donation as a Solution

Kidney transplantation has been clearly demonstrated to be the optimal treatment for patients with end-stage renal disease (ESRD), with transplant recipients showing dramatic improvements in survival over patients remaining on dialysis (Rodrigue et al. 2013). However, organ availability

has proven to be the major obstacle to expanding the application of kidney transplantation for these patients, and expanding the donor pool became imperative as waiting times increased for potential recipients. As a paired organ, the kidney is ideally suited for living donation, and living kidney donation emerged as a potentially promising solution to organ shortage (Segev et al. 2010).

Since 1954, it is estimated that over half-a-million living kidney donations have been performed worldwide, with the majority of those coming from the United States and India (Reese et al. 2015). The introduction of laparoscopic donor nephrectomy in 1995 helped reduce much of the morbidity associated with open donor nephrectomy, contributing to the dramatic rise in living kidney donations over the coming years. In the United States, the number of living donor kidney transplants has increased from 1817 in 1988 to 6388 in 2009. This number has since dropped and plateaued, with 5632 procedures performed in 2016 as seen in Fig. 1 (Rodrigue et al. 2013; OPTN 2017a; Branger and Samuel 2015).

Benefits of Living Kidney Donation

Over the last 30 years, the benefits of living kidney donation for recipients have been clearly demonstrated in the literature. Given that time on dialysis is the strongest predictor of patient outcomes, and that decreased time on dialysis leads to longer graft survival, live donor kidney transplant (LDKT) outcomes have proven to be superior to deceased donor kidney transplant (DDKT) in patients with ESRD (Rodrigue et al. 2013; Meier-Kriesche and Kaplan 2002; Meier-Kriesche et al. 2004). Compared to DDKT, LDKT has been associated with decreased time on wait lists, prolonged kidney allograft survival, increased life-years after transplant, decreased length of stay, and decreased hospital costs (Terasaki et al. 1995; Smith et al. 2000; Mange et al. 2001; Meier-Kriesche and Kaplan 2002; Abecasis et al. 2008; Axelrod et al. 2010). With LDKT, patients are able to get off the transplant list sooner and to stay off of the list for a longer duration. This combination of effects has had a profound impact on containing the number of patients on the list at any given time (Rocca et al. 1995).

Considerations for Donors and the Rise of Laparoscopic Donor Nephrectomy

Despite the dramatic improvements in outcomes offered by LDKT to the recipient, there remained a major ethical debate regarding its implementation due to the morbidity, mortality, and costs incurred by living donors. In 1995, the University of Wisconsin published their 28-year experience with live donor open nephrectomy that included 681 patients from 1971 to 1991. At the time, there were 4000–5000 cadaveric donors per year, a

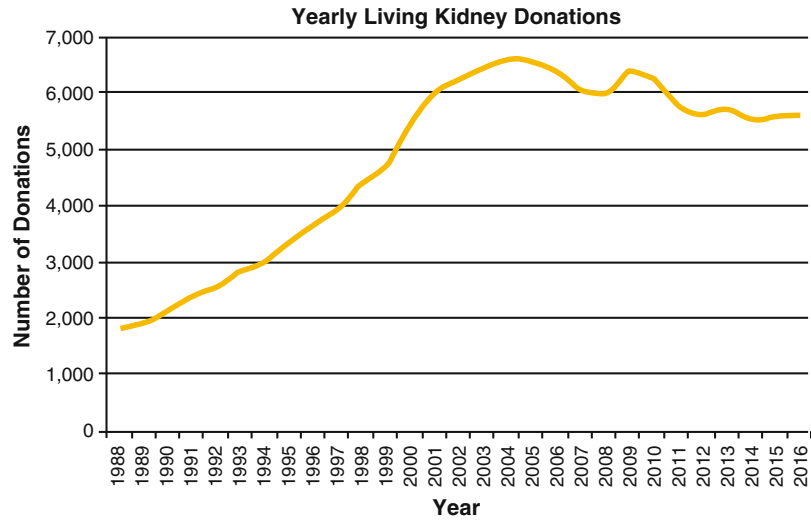

Fig. 1 Annual number of living kidney donations in the United States from 1988 to 2016

number that had remained relatively static despite the growing waiting list of recipients. They reported a 17% complication rate for donors, including pneumothorax, UTI, wound infection, pneumonia, and pulmonary embolus; only one death was reported, which was due to pulmonary embolism. In their experience, the live donor program accounted for one-third of the institution's volume. They placed great emphasis on the need to encourage living donations as a source of potential kidneys for the 27,000 listed potential recipients at the time (D'Alessandro et al. 1995).

The introduction of laparoscopic donor nephrectomy, first reported by Ratner et al. in 1995, offered the ideal solution to a number of logistical and financial disincentives to live donation (Ratner et al. 1995). Laparoscopic donor nephrectomy afforded less postoperative pain, shorter hospital length of stay, and postoperative convalescence for the donor patient with equivalent recipient outcomes compared to open donor nephrectomy. Overall complication rates were initially similar for laparoscopic versus open donation but were shown to decrease with improved surgeon experience (Ratner et al. 1997; Lee et al. 2000). Over the following decade, laparoscopy became the preferred technique at many institutions, leading to increased access to living donation for recipients (Flowers et al. 1997; London et al. 1999; Odland et al. 1999; Ratner et al. 1999).

Evaluation of Potential Living Donors

Requirements for Living Kidney Donation

According to the current guidelines from the Organ Procurement and Transplantation Network (OPTN), potential living donors must undergo extensive evaluation prior to donation. All living donors should undergo psychosocial evaluation to evaluate for any psychological and mental health issues, as well as to evaluate for behaviors that could place the donor at higher risk of poor psychosocial outcomes. Donors are also assessed for potential sources of coercion or external pressure for donation and must express understanding of the potential financial implications of living donation. The OPTN also requires the designation of an Independent Living Donor Advocate (ILDA). The ILDA is a third-party person or team that is completely independent from the recipient's medical team and whose main responsibility is to advocate for the living donor. Finally, an extensive medical evaluation must be completed and a thorough informed consent must be obtained prior to proceeding with living donation. The relative and absolute contraindications to living kidney donation vary based on guidelines and institutional protocols (Delmonico et al. 2005; Abramowicz et al. 2015; OPTN 2017b; Joint Working Party of the British Transplantation Society 2011). The evaluation of potential living donors is discussed in detail in chapter ▶ "Living Donor Evaluation and Selection."

Risks Associated with Living Kidney Donation

As the only operative intervention to offer no direct benefit to the patient, living donation offers a very unique set of challenges and ethical considerations not to be taken lightly. In addition to a rigorous preoperative workup, the operating surgeon should have an extensive discussion of the risks inherent to surgery as a whole, and also those specific to donor nephrectomy. Fortunately, an extensive amount of data has become available over the last 20–30 years regarding specific donor outcomes. However, these have often been limited by their retrospective nature, high loss to follow-up, and short time-frames. Furthermore, many of these studies have drawn comparisons to the general population, which is often not as thoroughly screened as the healthy living donor population (Ommen et al. 2006; Lentine and Segev 2013). Given these limitations and the many inherent biases to these studies, as well as their sometimes discordant results, it can be very difficult to convey the exact risks to patients. Further adding to the complexity of this discussion is the fact that many of the complications inherent to donor

nephrectomy can be dramatically influenced by various demographic and socioeconomic factors (Lentine and Segev 2013). For this reason, the discussion with patients should be highly individualized.

Morbidity and Mortality

Morbidity

The overall complication rate for donor nephrectomy is estimated to be between 7.9% and 22%, with major complications comprising an estimated 2.5–6% (Mjøen et al. 2009; Lentine and Patel 2012; Schold et al. 2013; Lentine et al. 2016). Lentine et al. found a 16.8% overall complication rate in the perioperative period, which consisted of 4.4% gastrointestinal complications, 3.0% bleeding, 2.5% respiratory, and 2.4% surgical/anesthesia related injuries, with all other complications comprising 6.6% (Lentine and Patel 2012). Schold et al. reported a 7.9% complication rate using data from the National Inpatient Sample (NIS) and the Scientific Registry of Transplant Recipients (SRTR) database, incorporating data for patients operated on between 1998 and 2010. The authors reported the proportion of significant complications as gastrointestinal (32%), respiratory (14%), puncture or laceration (11%), infectious (9%), and cardiac (4%). Importantly, the overall incidence of these complications declined over the study period (Schold et al. 2013). In a similar study evaluating hospital readmission, Schold et al. estimated 1- and 3-year rehospitalization rates to be 5% and 11%, respectively, with 21% of cases related to pregnancy, 14% digestive, 13% injuries and "poisoning," 8% genitourinary, 6% psychiatric, 5% musculoskeletal, 5% neoplastic, and 4% diseases of the circulatory system (Schold et al. 2014). Common factors associated with increased risk of complications are African American race (OR 1.26), male sex (OR 1.37), hypertension (OR 3.35), obesity (OR 1.55), hematologic conditions (OR 2.78), psychiatric conditions (OR 1.45), and robotic nephrectomy (OR 2.07) (Schold et al. 2013; Schold et al. 2014; Lentine et al. 2016). High-volume centers infer a protective effect, with centers performing more than 50 live donor nephrectomies per year showing decreased complications with an odds ratio of 0.55 (Lentine et al. 2016).

Mortality

Overall mortality after donor nephrectomy is extremely low. Evaluating a total of 80,347 live donors from the OPTN registry from 1994 to 2009, Segev et al. estimated a 90-day mortality of 3.1 per 10,000 live donors, which did not change over the 15-year observational period (Segev et al. 2010). Comparing 2028 Canadian living donors to healthy nondonors, Garg et al. estimated the risk of death and major cardiovascular complications to be lower in donors (2.8 vs. 4.1 per 1000 person years) over a median follow-up period of 6.5 years (Garg et al. 2010). Although most studies appear to indicate no increase in mortality with living kidney donation, there exists one study that demonstrates diminished survival in live donors (Mjøen et al. 2014).

Chronic Kidney Disease, End-Stage Renal Disease, and Other Renal Complications

Chronic Kidney Disease and End-Stage Renal Disease

Living kidney donation may elevate the risk of developing ESRD. However, despite the fact that half of the donor functional renal mass is removed at the time of donation, ESRD remains a very rare outcome in living donors. Intuitively, glomerular filtration rate (GFR) drops by approximately 50% immediately post-donation. However, because of compensatory hypertrophy and hyperfiltration by the remaining native kidney, GFR usually returns to approximately 70% within 3 months post-donation (Garg et al. 2006; Rook et al. 2006; Barri et al. 2010; Kasiske et al. 2013).

Although early literature seems to suggest equal risk for ESRD in living donors as compared to the general population (Cherikh et al. 2011), these early studies were limited by the fact that the general population was likely less healthy than the

heavily screened donors deemed suitable candidates for donation. More recently, Mjoen et al. found an incidence of ESRD of 0.47% in a population of Norwegian kidney donors with a median follow-up of 15.1 years (Mjøen et al. 2014). Muzaale et al., using a cohort of 96,217 live kidney donors in the US, found an incidence of ESRD of 0.31% at 15 years post-donation compared to 0.03% in matched healthy nondonors (Muzaale et al. 2014).

Evaluating Potential Donors for Renal Disease

Given the risk of developing ESRD, evaluating potential donors for baseline renal function remains an essential part of donor evaluation. Traditionally, most transplant centers in the United States only offered living donation to patients with a GFR above 80 mL/min/1.73 m^2, as this threshold was classically associated with lower graft failure rates in recipients (Nordén et al. 2000). Various methods of measuring GFR have been described and vary depending on institutional preferences. 24-hour urine collection is the most commonly used method, although measurement of urinary clearance of various tracers such as Iohexol, technetium 99mdiethylenetriaminepentaacetic acid (Tc99-DTPA), and other renally cleared tracers are gaining popularity (Mandelbrot et al. 2007). Recently, use of contrast-based imaging as a dual modality for anatomic evaluation and GFR measurement has been proposed, as some contrast media are strictly renally cleared, making them ideal for GFR measurement. However, this method of evaluating renal function has yet to gain a stronghold in donor evaluation (Rocca et al. 2012). In addition to GFR, potential donors are also screened for proteinuria, as this is a well-established risk factor for the development of CKD (Iseki et al. 2003) and is often considered a contraindication to donation. Hematuria is also evaluated since this may be an indication of underlying renal disease in potential donors.

Other Potential Kidney-Related Complications

Living kidney donors may develop other sequelae of decreased renal function, including a rise in serum uric acid and parathyroid hormone (Rossi et al. 2014; Kasiske et al. 2015). Lam et al. estimated an incidence of gout of 1.4% at 8 years post-donation, making living kidney donors 1.6 times more likely to develop gout post-donation than healthy matched nondonors (Lam et al. 2015b). African American race, older age, and male sex confer an increased risk of developing gout post-donation (Lam et al. 2015b; Lam et al. 2015a). Despite the rise in PTH and fibroblast growth factor-23 (FGF23) post-donation (Moody et al. 2016), Garg et al. demonstrated no increased fracture risk in donors as compared to healthy nondonors at a median of 6.6 years follow-up (Garg et al. 2012b).

Race and the Risk of ESRD Post-Donation

African American donors are at highest risk (four times higher) of developing ESRD post-donation, a trend that is consistent with that seen in the general population as compared to white individuals (Muzaale et al. 2014; Lentine et al. 2010). Gibney et al. found that 48% of living donors who require listing for kidney transplant themselves are African American (Gibney et al. 2007). Using a calculation tool to project estimated long-term incidence of ESRD based on various population characteristics, Grams et al. found a 15-year risk projection of 0.24% and 0.15% in black male and female donors respectively, compared to 0.06% and 0.04% in their Caucasian counterparts (Grams et al. 2016). In addition, black donors are also at increased risk of developing various renal complications including CKD, proteinuria, nephrotic syndrome, and other renal diagnoses (Lentine et al. 2015). Although these disparities can be partially explained by population-based socioeconomic factors and access to care, new evidence appears to suggest that genetic factors may play a role in this racial disparity (Gibney et al. 2007).

Hypertension

In addition to an increase in risk for ESRD, a rise in blood pressure is also a well-known complication of living donor nephrectomy. Boudville et al. estimated an increase in mean arterial blood pressure of 5 mmHg above the rise in blood pressure

expected by aging alone at 5–10 years post-donation (Boudville et al. 2006). Garg et al. found that at a mean follow-up of 6 years, 16.3% of donors developed a new diagnosis of hypertension compared to only 11.9% in a cohort of healthy adults (Garg et al. 2008). It is known that every 10 mmHg increase in systolic blood pressure and every 5 mmHg increase in diastolic BP confers a 1.5-fold increase in death from cardiovascular disease (Lewingston et al. 2002), theoretically increasing the risk of cardiovascular complications in the living donor population. Despite this fact, there has been no demonstrated increase in the incidence of cardiovascular disease in donors (Garg et al. 2012a; Moody et al. 2016).

Pathogenesis of Hypertension Post-Nephrectomy

Although the mechanism is poorly understood, it is thought that the compensatory hyperfiltration in the remaining native kidney and resultant alterations in renal blood flow and subsequent effects on the renin-angiotensin-aldosterone system may contribute to this increase in blood pressure. Additionally, more stringent long-term follow-up in donors is thought to potentially explain the increased incidence of the diagnosis of hypertension as compared to healthy matched controls (Garg et al. 2008).

Race and the Risk of Hypertension Post-Nephrectomy

Special mention should be made to specific patient populations with regard to hypertension post-kidney donation. Race has strong implications in the development of post-donation hypertension, with African American donors at highest risk of hypertension (Lentine et al. 2014b). Lentine et al. estimated an increased risk of 52% and 36% among African American and Hispanic donors respectively, as compared to white donors (Lentine et al. 2010). Similarly, African Americans are 37% more likely to be on antihypertensive medications post-donation (Lentine et al. 2014a). African American donors on Medicare are 2.4 times more likely to develop malignant hypertension than Caucasian Medicare donors (Lentine et al. 2014b). In a study of 103 African American donors, Doshi et al. showed a 40.8% incidence of hypertension post-donation compared to 17.9% in controls matched for age, sex, race, and baseline blood pressure at a median follow-up of 4.4 years, suggesting an unusually strong susceptibility to development of hypertension in African American donors (Doshi et al. 2013).

Pregnancy and Hypertension-Related Complications Post-Nephrectomy

Gender also has an impact on hypertensive complications after living donor nephrectomy. In comparing pre-donation pregnancies to post-donation pregnancies, Ibrahim et al. found an incidence of 5.7% gestational hypertension post-donation compared to 0.6% pre-donation, and an incidence of pre-eclampsia of 5.5% post-donation versus 0.8% pre-donation (Ibrahim et al. 2009). A similar study by Reisaeter et al. found an incidence of gestational hypertension of 5.7% post-donation compared to 2.6% pre-donation (Reisaeter et al. 2009). Both studies were limited by the simple fact that aging in women increases the risk of such pregnancy-related complications. In a retrospective cohort study matching 85 pregnant women post-donation to healthy matched controls, Garg et al. found an incidence of gestational hypertension or pre-eclampsia of 11% in donors compared to 5% in healthy controls. Importantly, there was no significant difference in maternal or fetal outcomes between the two groups (Garg et al. 2015).

Demographics and Other Considerations in Potential Live Donors

The increased risks associated with African American race and pregnancy have been clearly demonstrated, as detailed above. In discussing potential donation, other factors should be considered prior to proceeding.

Obesity

Another patient population deserving of particular mention is the obese population. Obesity is a well-established risk factor for the development of

hypertension and diabetes, both of which are known to contribute to the development of end-stage renal disease. Additionally, obesity itself has been shown to be a risk factor for the development of proteinuria and/or renal insufficiency after nephrectomy (Praga et al. 2000; Iseki et al. 2004; Kincaid-Smith 2004). It is this concern that has led transplant centers to adopt various cutoffs for BMI as part of the consideration for donation. In a 2007 survey of United States Transplant Centers, 10% of centers used a BMI of 30 kg/m^2 as a threshold for consideration, while 52% used a BMI of 35 kg/m^2, and 20% use a BMI of 40 kg/m^2 as a cutoff. Six percent considered BMI with other cardiovascular risks, and 12% had no cutoff at all (Mandelbrot et al. 2007).

Donor Age

Another important consideration in assessing potential donors is patient age. There has been growing concern in the use of young donors for living donation, as the lifetime risk of developing ESRD in young healthy patients has been estimated to be 2–3% in whites and 7% in African Americans. Currently, most guidelines will decline patients with risk factors for ESRD. Given that younger donors who are bound to develop ESRD in the future have not had the time necessary to exhibit many of those risk factors, the argument has been made that too much comfort is taken in using young "healthy" donors, as a significant number are destined to develop ESRD. Comparatively, older donors without risk factors for ESRD are themselves much less likely to develop ESRD, having lived many years without developing risk factors (Steiner 2010). It is in this young healthy donor population that better estimations of risk for donation based on variables such as race, gender, and socioeconomic status should be established more clearly.

Choosing the Right Versus Left Kidney

As elicited in the OPTN guidelines for evaluation of potential donors, detailed imaging should be obtained to assess donor kidneys for lesions that could prevent donation, such as masses, cysts, or stones. Imaging can also help determine which kidney to procure. CT and MRI are the most commonly used modalities to delineate renal and renovascular anatomy. Traditionally, the left kidney has been preferred for retrieval given its longer renal vein. Furthermore, procurement of the left kidney has been associated with decreased operative times and easier reimplantation in the recipient. However, recent literature suggests that with the advent of laparoscopy, using the right kidney leads to equivalent outcomes for both recipient and donor (Buell et al. 2001; Mandal et al. 2001; Bettschart et al. 2003; Kay et al. 2006; Narita et al. 2006; Hoda et al. 2010; Hoda et al. 2011). These findings were corroborated in a recent meta-analysis by Wang et al. (2015). Although retrieval of the left kidney is generally preferred, there should be no hesitation to use the right kidney, especially in cases where the left kidney may have questionable lesions or multiple arteries.

Surgical Technique

The laparoscopic donor nephrectomy has become the mainstay of living donation. While there is variability regarding the peculiarities of the operation at individual institutions, the operation proceeds in generally the same fashion. One major distinction that exists is hand-assisted vs. pure laparoscopic donor nephrectomy. Herein, the various techniques available for donor nephrectomy are described, beginning with a description of pure laparoscopic donor nephrectomy, followed by the hand-assisted approach. Finally, two other minimally invasive techniques have been described, namely the single incision laparoscopic surgery (SILS), and the robotic donor nephrectomy, which will be discussed below.

Pure Laparoscopic Approach

The technique of pure laparoscopic donor nephrectomy has been well described by Fabrizio et al., and the operative description for the left-sided

approach that follows, as well as the associated figures are taken directly from the authors' description with permission (Fabrizio et al. 1999).

Technique for Left-Sided Pure Laparoscopic Approach

After induction of general anesthesia, broad spectrum antibiotics are administered, a foley catheter is placed along with an orogastric tube to be removed at the completion of the case. Adequate intravenous (IV) access is mandatory and generally consists of two large bore peripheral IV lines. The patient is then positioned in a modified flank position, placing the torso in a 45° lateral decubitus position. To enhance exposure to the lower abdominal midline, the hips are rolled slightly backward. Next, the arms are brought to chest level in a semiflexed position and the patient is secured to the operating table with straps. Care is taken to appropriately pad the axilla and lower extremities, and the patient is appropriately flexed, as seen in Fig. 2. Next, proper configuration of the operating room is ensured, as noted in Fig. 3.

The authors prefer to establish pneumoperitoneum using a Veress needle, insufflating to a pressure of 15 mmHg. Using an optical trocar and zero-degree lens, the first 10–12 mm port is placed lateral to the rectus muscle midway between the umbilicus and iliac crest. Under direct visualization, the second 10/12 mm port is then placed at the umbilicus, followed by a 5 mm port, which is placed midline between the umbilicus and xyphoid process, as illustrated in Fig. 2. A 30-degree scope is used for the remainder of the procedure, using the umbilical port as the camera port during the dissection.

Starting at the splenic flexure, atraumatic graspers placed in the 5 mm port and a Ligasure device (Valleylab, Boulder, CO) placed in the lateral port are used to reflect the ipsilateral colon medially to the level of the sigmoid by incising the lateral peritoneal reflection (Fig. 4). To allow the colon to be completely reflected medially, the phrenocolic ligaments at the level of the splenic flexure must be completely divided. Next, the spleen is retracted superiorly by dividing the lienorenal and splenocolic ligaments at the inferior border of the spleen. Finally, the colorenal ligaments are divided, allowing full exposure of Gerota's fascia. Next, the kidney is freed within Gerota's fascia (Fig. 5). Care must be taken to avoid inadvertent injury to the kidney, spleen, and renal hilum, as this is one of the most challenging portions of the procedure. Electrocautery can be used, maintaining caution to avoid any thermal injury to the colon.

Next, attention is turned to mobilization of the kidney. The border of the upper pole is identified, making sure not to confuse lobulations for the border of the upper pole. Once properly identified, gentle elevation of the upper pole with a blunt instrument will facilitate dissection (Fig. 5). Regardless of the instrument chosen for retraction (a 5 mm irrigation/suction device is preferred), retraction should be performed under direct visualization, advancing the tip of the retractor along the sidewall so as to prevent inadvertent injury to the surrounding organs. The upper pole

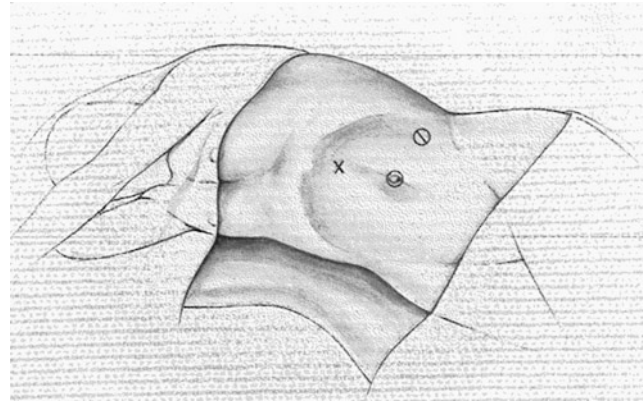

Fig. 2 Patient position. The arms are flexed and the hips rolled slightly posterior. The three port placements, 10/12 mm, 10/12 mm, and 5 mm, are noted

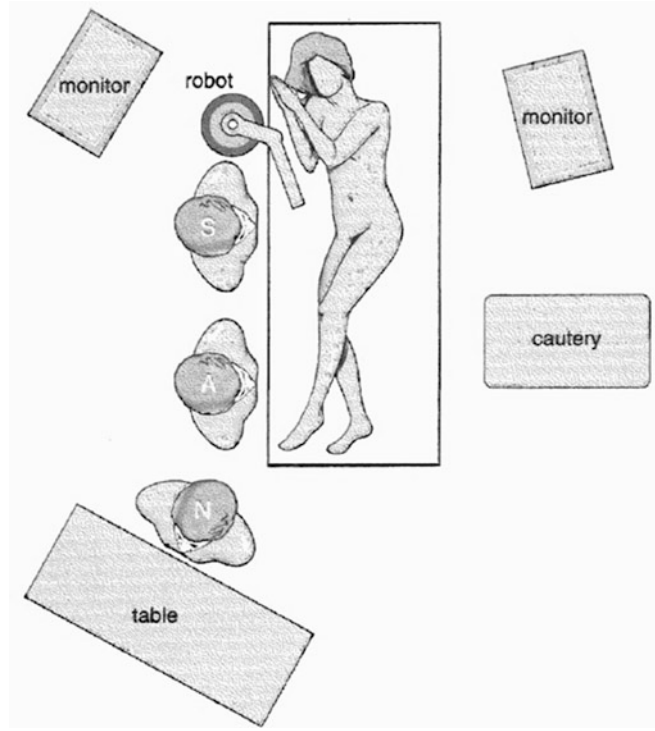

Fig. 3 Operating room configuration

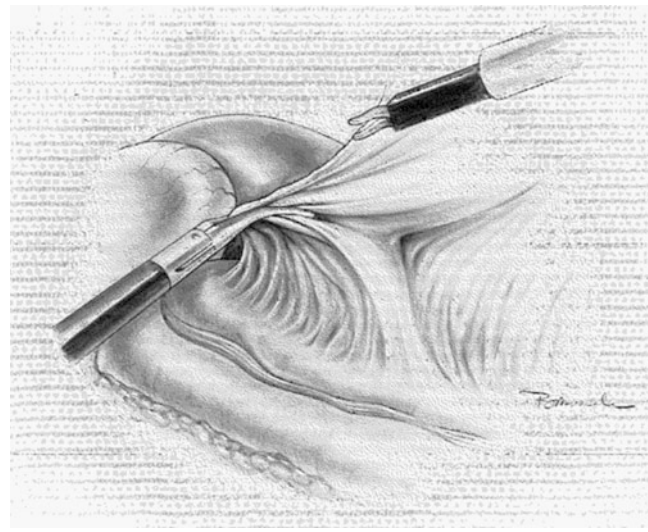

Fig. 4 Incising the lateral peritoneal reflection (line of Toldt) and reflecting the colon medially

attachments are completely freed using both blunt and sharp dissection, and attention is then turned to exposing the hilar vessels.

Incising Gerota's fascia medially should bring the renal vein into view. Next, the renal vein is completely isolated by freeing it from its adventitial attachments. The gonadal, adrenal, and lumbar veins are identified and are cauterized and divided using the Ligasure device (Valleylab, Boulder, CO) (Fig. 6). To facilitate exposure of

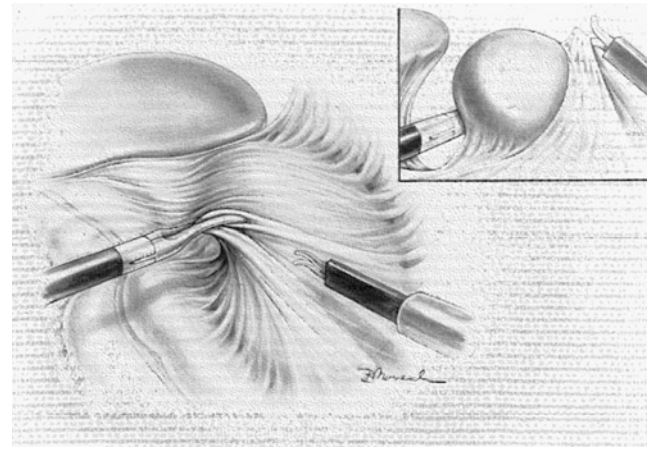

Fig. 5 Division of the colorenal ligament and exposure of Gerota's fascia. Inset illustrates the upper pole of the kidney which has been freed and elevated

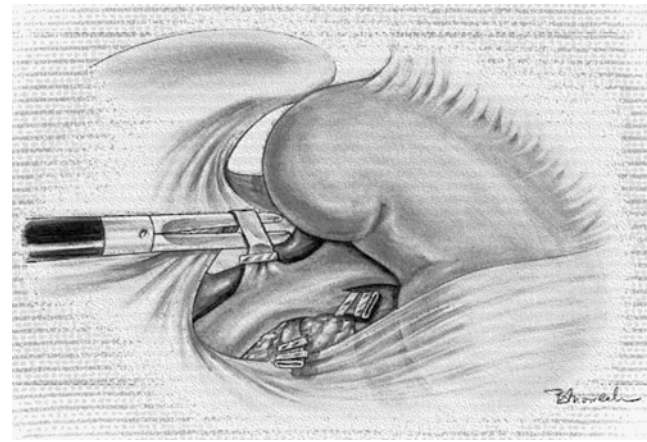

Fig. 6 After exposing the renal vein, the gonadal and adrenal veins are clipped and divided. Note the forceps under the adrenal vein

the lumbar veins, the renal vein can be lifted with gentle traction. Care should be taken during dissection of the renal vein, as overly aggressive dissection can result in bleeding from the adrenal vessels, which can be difficult to control. The renal artery, lying posterior to the renal vein can now be identified and isolated via sharp dissection to separate it from its extensive surrounding lymphatics. Here, the Ligasure device (Valleylab, Boulder, CO) is carefully employed to prevent lymphatic leakage. Lastly, the renal artery is completely dissected to its origin at the aorta to ensure maximal exposure, and the patient is administered 20 mg of IV furosemide.

To prevent torsion of the kidney on its dissected vascular pedicle, the lateral, posterior, and inferior attachments are left intact, forming a three-point fixation. Next, the ureteral dissection is commenced inferiorly. The gonadal vein is identified inferior to the renal hilum and a plane is created medially toward the side wall. The dissection then proceeds inferiorly and the gonadal vessels are transected at the level of the pelvis using the Ligasure device (Valleylab, Boulder, CO). Dissection of the ureter continues inferiorly to the level of the left iliac vessels, where it is divided using a clip applier and laparoscopic scissors (Fig. 7). Next, the inferior and lateral attachments to the kidney are divided. Lastly, the posterior attachments are divided using gentle elevation of the upper pole, leaving the kidney attached only by its vascular pedicle.

Prior to dividing the vascular pedicle, a 5 cm Pfannenstiel incision is made, extending the incision through fascia, without violating peritoneum

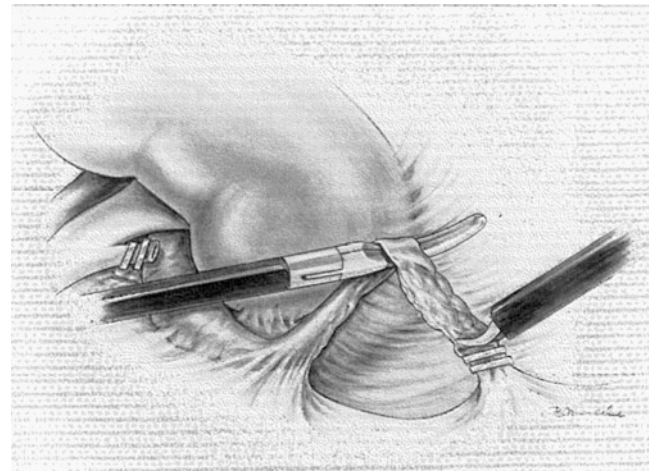

Fig. 7 Division of the ureter at the level of the iliac vessels. Care is taken to preserve abundant periureteric tissue

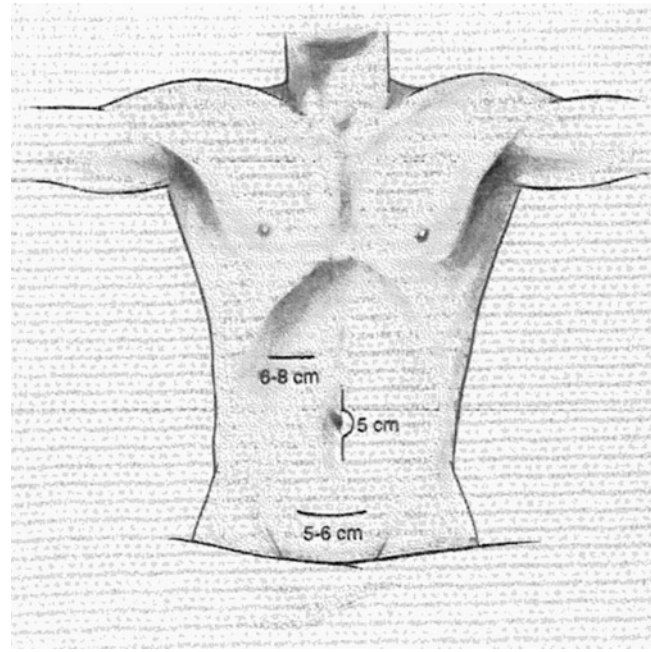

Fig. 8 The locations of the three possible incisions employed for delivery of the kidney. The right upper quadrant, midline, and Pfannenstiel incisions are noted

(Fig. 8). A purse-string suture is then placed into the peritoneum and a trocar is inserted to allow insertion and deployment of an Endocatch bag (Covidien, Mansfield, MA). The camera is then moved to the left lower quadrant port, and an Endo GIA stapler (Covidien, Mansfield, MA) is used to divide the renal artery first (Fig. 9), followed by the renal vein (Fig. 10). The free kidney is then reflected over the spleen by grasping the perirenal adipose tissue and is placed into a 15 mm Endocatch bag (Covidien, Mansfield, MA) inserted through the Pfannensteil incision. Up to this point, care should be taken to avoid violating the peritoneum so as to maintain pneumoperitoneum. Once the kidney is secured in the Endocatch bag (Covidien, Mansfield, MA), the peritoneum is incised and the kidney is delivered through the Pfannensteil incision, making

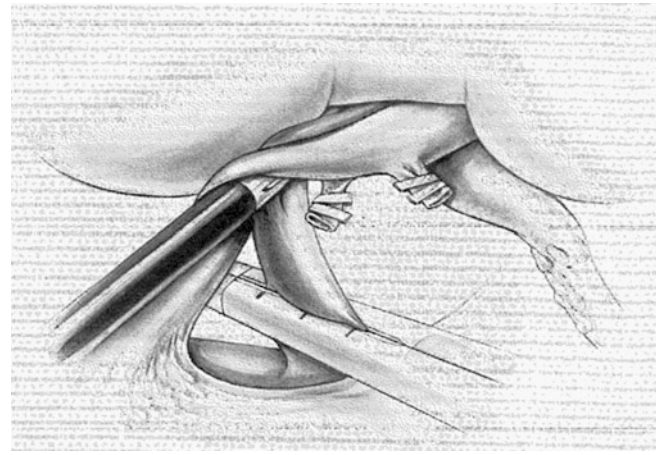

Fig. 9 Division of the vascular pedicle – division of the renal artery

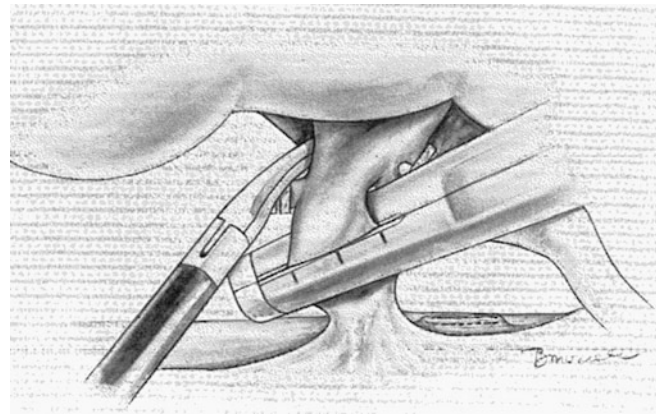

Fig. 10 Division of the vascular pedicle – division of the renal vein

sure to lengthen the incision as needed to ensure completely atraumatic delivery. The kidney is then transferred to the recipient team.

Number 1 polydioxanone (PDS) suture is used to close fascia in interrupted fashion, and pneumoperitoneum is reestablished. Hemostasis is ensured with careful examination of the renal bed, followed by the trocar sites. The lateral port site is closed under direct visualization using the Carter-Thomason closure device (CooperSurgical, Trumbull, CT) with 2–0 Vicryl suture. The camera is removed and pneumoperitoneum is evacuated via the periumbilical port. The umbilical port site is closed utilizing a figure of 8 suture. The skin is then closed with 4–0 Monocryl suture and adhesives are applied to the incisions (Fabrizio et al. 1999).

Technique for Right-Sided Pure Laparoscopic Approach

In the right-sided approach, as described by Chow et al., the patient is placed in the left lateral decubitus position. As in the left-sided approach, transperitoneal access is obtained and pneumoperitoneum established in the standard fashion. Ports are placed in the following locations: one halfway between the umbilicus and the xiphoid, one halfway between the pubic symphysis and the umbilicus, and a final port lateral to the rectus muscle on the right side at the level of the umbilicus. The right colon is mobilized and a Kocher maneuver is performed. The posterior and lateral attachments of the liver are released to allow it to be reflected to expose the right renal hilum. An

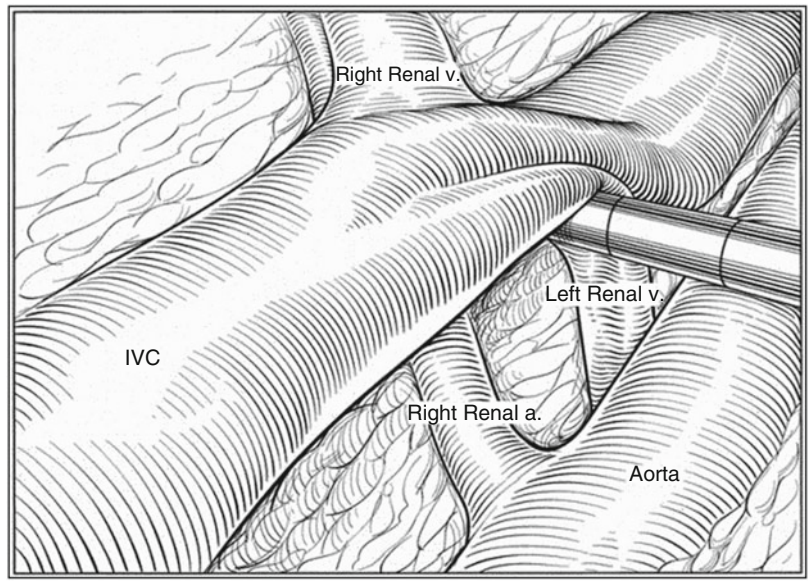

Fig. 11 Diagram illustrating anatomy of interaortocaval region. Superior retraction of the vena cava is used to expose the interaortocaval area (Image reproduced with permission by Chow et al.)

additional 3-mm port is placed in the subxyphoid area, and a locking grasper or liver retractor is utilized to assist in hepatic retraction.

The right renal vein is dissected and mobilized. This allows exposure of the right renal artery posteriorly. Blunt dissection in the interaortocaval area is used to identify the origin of the right renal artery. It is important to ligate or clip lymphatic tissue prior to division to prevent lymphocele. The retrocaval artery is mobilized by careful upward retraction of the vena cava and blunt dissection along the artery (Fig. 11). The lumbar veins should be identified and ligated to afford sufficient mobilization of the vena cava. The artery is then dissected free circumferentially, and the procedure proceeds in a manner similar to that of the left-sided approach. The vessels are transected with an Endo GIA stapler (Covidien, Mansfield, MA). The artery is incised at its take off from the aorta (Chow et al. 2001).

Hand-Assisted Donor Nephrectomy

Technique

The patient is brought to the operating room and placed on the operating table in the supine position with the flanks overlying the break in the table. General anesthesia is then induced with endotracheal tube placement. A foley catheter is placed. At this point, the patient is repositioned in the lateral decubitus position. In the case of a left donor nephrectomy, the right side is decubitus. Care is taken to adequately pad the head, so the neck is in a neutral position. An axillary roll is placed just inferior to the axilla. Two blanket rolls are utilized in conjunction with the draw sheet to secure the patient in the lateral position. Some centers utilize a suction beanbag, but the authors' approach offers a similar result with less complexity. The dependent arm is placed in the bent position and padded at the elbow. The left arm is suspended by way of an arm sling. The legs are positioned such that the dependent leg is bent and the nondependent leg is fairly straight. The knees and ankles are padded to ensure a neutral position. Towels are placed caudal and cephalad to the operative field, and the patient is secured to the operating table with 3-inch silk tape. The bed is then flexed approximately 15° to enhance the operative field. Upper and lower Bair-Huggers (3 M, St. Paul, MN) are placed.

The patient is then prepped and draped as is typical for a laparoscopic procedure. A periumbilical incision is made, typically 6.5 cm in length. Electrocautery is used to dissect through the subcutaneous tissue, open the fascia, and enter the peritoneum. Typically, a Gelport (Applied

Medical, Rancho Santa Margarita, CA) is placed at this incision and a 12 mm trocar is placed through the Gelport (Applied Medical, Rancho Santa Margarita, CA). The abdomen is insufflated through this port to 12 mmHg. A 10 mm camera is then inserted through this same port and the abdomen is inspected for any potential injury or adhesions. At this point, 5 mm trocars are placed in the lateral and subcostal positions. These are placed under direct visualization, and care is taken to avoid the epigastric vessels with the placement of the subcostal port. The camera is then switched to a 5 mm 30° scope, which is inserted through the subcostal port.

At this point, the dissection can move forward. The surgeon's left hand is inserted through the hand port and a Harmonic scalpel (Ethicon, San Angelo, TX) is typically utilized through the lateral 5 mm port. The dissection is initiated by mobilizing the left colon. The mesentery is mobilized by dividing the peritoneum just superficial to the white line of Toldt. This ensures that the dissection does not proceed posterior to the kidney. This dissection is carried down to the iliac vessels and extended cephalad to mobilize the spleen along with the colon in one unit. This will expose Gerota's fascia and the gonadal vein. Care is taken not to dissect too close to the pancreas to avoid inducing pancreatitis.

At this point, the surgeon is able to palpate the kidney and assess the extent of the upper pole, lower pole, and the location of the hilum. From here, there are two approaches to the hilar dissection. In the authors' dissection, the Gerota's fascia is entered directly and the renal vein is identified. It is important throughout the dissection to maximize the use of the left hand to gently retract tissue for division or provide counter tension. Once the anterior surface of the renal vein is dissected clear, the next step is to identify the insertion of the gonadal and adrenal veins. Through a combination of the Harmonic scalpel (Ethicon, San Angelo, TX) and the Maryland dissector, adequate length of the gonadal and adrenal veins are dissected out to allow double clip ligation and division of each vein. This allows for circumferential dissection of the renal vein towards the vena cava and exposure of the renal artery. The anterior surface of the renal artery is dissected clear utilizing the hook cautery or the Harmonic scalpel (Ethicon, San Angelo, TX). The hook cautery is preferred as it allows the careful division of overlying tissues without injuring the posteriorly located artery. The adrenal gland is then dissected free of the upper pole of the kidney. This dissection proceeds by identifying the adrenal gland and dissecting from the renal vein to the upper pole. The ureter is identified lateral to the gonadal vein near the lower pole of the kidney. It, along with the surrounding fat, is dissected out of the retroperitoneum down to the level of the iliac vessels.

Once the ureter has been circumferentially mobilized, the lower pole of the kidney can be mobilized out of the retroperitoneum. The dissection remains close to the surface of the kidney and proceeds from lower pole to upper pole, lateral to medial. The surgeon's hand may be utilized to gently retract the kidney away from the retroperitoneum to aid in dissection. Once the kidney is fully mobilized, the posterior aspect of the renal artery can be dissected clear of tissue. At this point, the kidney is fully mobilized and connected to the donor only via the renal artery, renal vein, and ureter. It is important during the dissection that the donor is kept normotensive, and the kidney should remain well perfused and fairly firm. Overmanipulation of the kidney or relative hypotension can result in the donated kidney becoming hypoperfused, leading to impaired immediate graft function. The ureter is then clipped distally and divided. To ensure immediate graft function, the surgeon watches the ureter for the production of urine. In the authors' experience, significant urine production after division of the ureter is a good marker of immediate graft function. Once the receiving surgeon is ready, the vessels can be divided. A stapling device is used to close and divide the renal artery first, followed by the renal vein. The kidney is then retrieved through the hand port and passed to the receiving surgeon.

Once brought to the backtable, the vessels are examined and the organ is flushed with preservation solution on ice until clear. During this time, the donor surgeon replaces the Gelport (Applied

Medical, Rancho Santa Margarita, CA) and insufflates the abdomen. The retroperitoneum is inspected and hemostasis is achieved through a combination of clips, cautery, and Harmonic scalpel (Ethicon, San Angelo, TX) as necessary. The origins of the renal artery and vein are examined to confirm hemostasis. Care must be exercised to examine the spleen and adrenal gland, as these can be a source of bleeding. Lastly, the area is examined to identify any potential lymph leak stemming from periaortic lymph channels, which are divided during the dissection and can leak. Failure to control lymph leaks prior to completing the operation can result in a lymphocele requiring further intervention.

Once the donor surgeon is satisfied, the abdominal contents are returned to their native positions and the ports can be removed. The 5 mm ports are removed under direct visualization to identify any port site bleeding prior to closure. The abdomen is then desufflated and the Gelport (Applied Medical, Rancho Santa Margarita, CA) is removed. The omentum is pulled inferiorly to cover the small bowel and to lay between the periumbilical incision and the bowel.

The peritoneum is closed with a 4–0 PDS suture. The midline fascia is then closed with number 1 PDS figure of eight sutures. All skin incisions are closed with 4–0 Monocryl running subcuticular sutures. Wounds are then dressed. The patient is repositioned in the supine position and anesthesia is discontinued.

Right nephrectomy is performed in a similar manner to that of the pure laparoscopic approach.

Single Incision Laparoscopic Surgery (SILS)

Technique

The SILS technique has been well described by Barth et al. in the detailing of the experience at the University of Maryland. The authors offer nephrectomy through a single transumbilical incision. In their experience, they have demonstrated equivalent complication rates, blood loss, and operating times. Despite a significant learning curve, the authors performed both laparoscopic and SILS surgery with equivalent outcomes by the completion of the study period (Barth et al. 2013). The operative description that follows is adapted from the description offered by LaMattina, et al. with permission (LaMattina et al. 2017).

After induction of general anesthesia, the patient is positioned in a lateral decubitus position. For left nephrectomy, a 2–3 cm SILS port (Covidien, Mansfield, MA) or a 4–5 cm Gelpoint (Applied Medical, Rancho Santa Margarita, CA) incision is made around the umbilicus. For a right nephrectomy, the Gelpoint (Applied Medical, Rancho Santa Margarita, CA) incision is always used. The abdomen is insufflated to 15 mmHg and is then visually explored. Next, using the Harmonic scalpel (Ethicon, San Angelo, TX) to minimize bleeding, the colon is mobilized from the splenic flexure to the pelvic brim. The kidney is then mobilized using blunt dissection.

Next, the ureter and gonadal vessels are dissected free from the renal hilum to the level of the iliac vessels. On the left side, this will expose the junction of the gonadal vein and renal vein. The lower border of the left renal vein and any lumbar vein are then exposed by gently elevating the lower pole with an atraumatic bowel grasper. Lumbar veins are divided with the Harmonic scalpel (Ethicon, San Angelo, TX), with larger veins potentially requiring division between clips. The Harmonic scalpel (Ethicon, San Angelo, TX) is then used to develop a plane between the adrenal gland and the kidney using lateral traction to facilitate the process. Next, the posterior renal attachments are freed and the renal artery is dissected circumferentially. Once isolated, the artery is dissected further up to its origin at the aorta and the renal vein is dissected past the level of the aorta. At this point, the left adrenal vein can either be left intact to be divided at the time of left renal vein division, or it can be dissected further and divided with a Harmonic scalpel (Ethicon, San Angelo, TX) to maximize left renal vein length.

When ready to explant the kidney, a 15 mm port is inserted through the single port device and an Endo GIA vascular stapling device (Covidien, Mansfield, MA) is used to divide the ureter and gonadal vein together at the level of the pelvic brim. Next, the renal artery and vein are divided

sequentially with the same stapling device and hemostasis is ensured at each staple line. The free kidney is then placed into a 15 mm Endo Catch bag (Covidien, Mansfield, MA) under direct visualization and the port is removed with specimen extraction. When using the SILS port, the skin incision needs to be extended by 1–3 cm depending on the size of the kidney, and the kidney is extracted in the bag atraumatically and transferred to the recipient team.

The fascia is partially closed, allowing for ports to be replaced and for pneumoperitoneum to be reestablished. The abdomen is explored one last time, ensuring hemostasis, and any mesocolonic defects are identified and repaired with metal clips or intracorporeal suturing. The ports are then extracted and pneumoperitoneum evacuated. The fascia is then closed with number 1 PDS suture. The skin is closed with 4–0 Monocryl suture and incisions are covered with adhesive dressings (LaMattina et al. 2017).

Again, this approach can be utilized for right donor nephrectomy, proceeding with similar adjustments to those made utilizing the pure laparoscopic technique.

Robotic Donor Nephrectomy

The University of Illinois-Chicago group published the largest series of robotic donor nephrectomy (Horgan et al. 2002). Their series essentially serves as a proof of concept for robotic donor nephrectomy as there currently exists no FDA-approved device for ligation and division of the renal vessels. In their series, they described a hand-assisted robotic approach that allowed the surgeon to utilize the superior optics and dexterity of the minimally invasive instruments to recreate the dexterity and hand-eye coordination experienced by the surgeon during open surgery. The operative times, complication rates, and lengths of stay were commensurate with those experienced in their own laparoscopic series. While this technique is in its infancy, this series does point to the possibility of robotic donor nephrectomy once robotic stapling and retrieval devices are perfected.

Complications

Complications after minimally invasive living donor nephrectomy have been described in numerous series. They are summarized in Table 1 based on descriptions by Ahearn et al. Among the most common minor complications are wound complications and infections. Major complications can include postoperative port-site hernias, intraoperative visceral injury, major hemorrhage, need for blood transfusion, and death (Ahearn et al. 2011). In addition, it is important to emphasize to the donor that, however rare, there may arise situations in which the operation is terminated or the kidney is sacrificed for the safety of the donor.

The most common complication after the SILS technique is a hernia at the umbilical port site, occurring in 3% of patients following donation.

Table 1 Complications of live donor nephrectomy with associated incidence

Major complications	Incidence
Readmission	1.0%
Blood transfusion	0.5%
Open conversion	0.3%
Lymph leak	0.3%
Port-site hernia	0.2%
Reoperation	0.2%
Renal insufficiency	0.2%
Rhabdomyolysis	0.1%
Minor complications	
Wound infection	1.9%
Ileus	0.5%
Urinary retention	0.4%
Urinary tract infection	0.4%
Pneumothorax	0.3%
Respiratory distress	0.2%
Pneumonia	0.1%
Intraoperative complications	
Splenic laceration	0.8%
Liver laceration	0.3%
Adrenal injury	0.2%
Venous injury	0.2%
Bowel injury	0.2%
Carbon dioxide embolism	0.2%
Ureteral injury	0.1%
Bladder injury	0.1%

Table derived from description by Ahearn et al.

In a series of 378 consecutive SILS nephrectomies, LaMattina et al. found that 92% of hernias occurred in women, and 73% of these women had had prior pregnancies. Fifty percent of donors who suffered a hernia had undergone prior transumbilical surgical procedures. Cross clamp time, estimated blood loss, BMI, age, and laterality of the donation were not associated with subsequent hernia formation. The hernias reported 13.5 months after donation were at the original port-site incision, with 2/3rd being repaired primarily and 1/3rd requiring mesh. 1.9% of patients required a return to the operating room for a variety of reasons, including internal hernia from a mesenteric defect in the mesocolon, wound infection leading to evisceration, bowel obstruction, bleeding, and persistent wound infection. There was a single open conversion, one intraabdominal abscess, and three patients who required a blood transfusion (LaMattina et al. 2017).

Postoperative Pain Control

There are multiple techniques for analgesia postdonation. With an increasing emphasis on early return to activity and shortened hospital stays, there has been a gradual turn away from narcotic-based analgesia plans. Many centers utilize multimodal nonnarcotic pain management regimens. These often include the use of local anesthetic or blocks, nonsteroidal anti-inflammatory medications, and acetaminophen.

Conclusion

Kidney transplantation is now well established as the best treatment modality for patients with ESRD. As the number of patients needing transplantation continues to grow, one of the major obstacles remains organ shortage. Living donor kidney transplantation has emerged not only as a way to give more patients access to kidney donation but also to improve outcomes in transplant recipients as compared to deceased donor kidney transplantation. As the only surgery to offer no direct benefit to the patient, a number of ethical issues have been brought up that are unique to living donation, specifically focusing on the risks to potential donors. With the advent of laparoscopy, laparoscopic donor nephrectomy has become the standard of care in suitable candidates and has significantly decreased the morbidity of living kidney donation. Nonetheless, outside of standard postoperative risks, specific lifetime risks remain in post-nephrectomy patients after donation. The lifetime increase in risks of developing ESRD and hypertension in donors is a concern in the literature. Further complicating the matter are issues such as the disparity in outcomes based on demographic and socioeconomic factors such as race, gender, BMI, and insurance status. These must all be taken into consideration when offering living kidney donation to patients, and the discussion of potential risks associated with surgery must be highly individualized and tailored to each patient. Such tools, as the risk calculator, devised by Grams et al. may be very useful adjuncts in the evaluation of individual donors for donation risks (Grams et al. 2016).

Cross-References

- ▶ Living Donor Evaluation and Selection
- ▶ Necessary Components of a Living Donor Team
- ▶ Organ Procurement Organization and New Kidney Allocation

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