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Critical Analysis of Laparoscopic Donor Nephrectomy in the Setting of Complex Renal Vasculature: Initial Experience and Intermediate Outcomes

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Abstract

Objective: We report our experience with laparoscopic donor nephrectomy (LDN) in the setting of complex renal vasculature and critically analyze the technique and intermediate recipient outcomes.
Methods: Thirty-nine living renal donors with multiple renal arteries or veins, or anomalous venous anatomy, who underwent LDN between 2003 and 2007 at our institution were retrospectively reviewed. Demographic and perioperative data were collected on donors and recipients.
Results: Complex vasculature consisted of multiple renal arteries in 26 cases (67%), multiple renal veins in 10 cases (26%), retroaortic renal vein in 5 cases (13%), circumaortic renal vein in 4 cases (10%), and a persistent left-sided inferior vena cava (IVC) in 1 case (3%). Thirty-four (87%) patients had a single anomaly and five (13%) had multiple anomalies. Mean operative time was 196.3 minutes (range 135–311 minutes), mean blood loss was 99.4 mL (range 25–400 mL), and mean hospitalization period was 2.6 days (range 1–4 days). Donor creatinine preoperatively and at discharge was 0.8 mg/dL and 1.2 mg/dL, respectively. Mean warm ischemia time was 168.9 seconds (range 90–300 seconds). Mean recipient creatinine at the time of discharge was 1.45 mg/dL, and nadir creatinine at 1 and 2 years follow-up was 1.41 mg/dL and 1.30 mg/dL, respectively. There were three (7.7%) intraoperative complications and two (5%) cases of allograft failure over the 2-year period.
Conclusions: LDN in patients with complex vascular anatomy is safe and efficacious and does not negatively impact the complication rate or recipient outcomes. This procedure may improve the availability of allografts.

Introduction

RENAL TRANSPLANTATION is the preferred long-term treatment option for patients with end-stage renal disease. During the past two decades, attempts have been made to expand the kidney donor pool as an increasing number of patients are requiring a renal transplant. Live donor nephrectomy was historically described as an open surgical procedure. The open approach has been associated with significant morbidity and extended convalescence, and has accounted for the reluctance to donation by otherwise healthy volunteers.[1]

Laparoscopic live donor nephrectomy (LDN) was introduced by Ratner et al in 1995 and is increasingly being used by transplantation centers worldwide.[2] The benefits of this minimally invasive approach to kidney donation, including less postoperative pain, earlier return to regular activity, and improved cosmesis, have resulted in an increased willingness to donate.[3,4,5] Importantly, no significant differences have been observed in creatinine clearance or in patient or allograft survival rates when comparing recipient outcomes for LDN with those for open live donor nephrectomy.[6–10]

As in open donor nephrectomy, the left kidney is preferred in LDN due to the longer left renal vein, which provides a more optimal vessel for venous reanastomosis in the recipient. It is well known that not all potential donors have a favorable anatomy conducive to left-sided LDN. Complex left renal vasculature, such as multiple renal arteries or veins, as well as other vascular anomalies have been cited as indications to disqualify a patient from renal donation or to consider right-sided donor nephrectomy at certain centers. However, critics of right-sided LDN point out the technical challenges of exposing the right renal hilum, and the fact that the right allograft is likely to have a shorter renal vein than the left.[11,12]

Previous reports on LDN in the setting of complex renal vasculature have consisted of relatively small, single-center series with limited follow-up. We presented our initial experience with this cohort of patients in 2006.[13] In the present study, we report our experience with LDN in patients with

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complex renal vasculature and critically analyze the technique and intermediate recipient outcomes.

Materials and Methods

Between 2003 and 2007, 39 living renal donors with complex vascular anatomy underwent LDN at our institution. Complex vasculature was defined as the presence of multiple renal arteries or renal veins, or anomalies of the renal vein including circumaortic vein, retroaortic vein, and persistent left-sided IVC. A retrospective analysis was performed to collect donor and recipient demographics and perioperative data. Preoperative donor evaluation consisted of history, physical examination, renal function testing with serum creatinine, and/or radionuclide renal scan. Three-dimensional spiral CT angiography was used to define the renal parenchyma and vasculature. At our institution, the left kidney is preferentially harvested unless the preoperative evaluation demonstrates that the left kidney contributes to the overall renal function significantly more than the right kidney.

Information on donor age, gender, relation to the recipient, and type of vascular anomaly was collected. Surgical data included operative time, warm ischemia time, estimated blood loss, complications, and nadir serum creatinine. Operative time was defined as the time from the initial skin incision to deliverance of the kidney to the recipient transplant team. Warm ischemia time was calculated as the time from renal artery ligation to immersion of the kidney in ice slush. Information was also collected on recipient allograft function, including serum creatinine at the time of discharge and at 1 and 2 years follow-up, as well as complications.

A transperitoneal laparoscopic approach was used in all cases. All donor nephrectomies were performed by a single urologic surgeon, and all renal transplants were performed by a single transplant surgeon. A conventional laparoscopic approach or a hand-assisted technique was used based on the surgeon's preference.

Initially, for pateints with multiple renal arteries, 2 Hem-o-lok clips (Teleflex Medical, Research Triangle Park, NC) were placed on each artery at its origin from the aorta, and each artery was transected on the allograft side with laparoscopic scissors. Since April 2006, arteries have been ligated with an endoscopic TA linear stapling device (U.S. Surgical, Norwalk, CT) and transected lateral to the staple line with laparoscopic scissors. An endoscopic TA linear stapling device was used to ligate single or multiple renal veins medial to the adrenal and gonadal branches. Laparoscopic scissors were used to transect each vein lateral to the staple line.

In the circumstance of a retroaortic renal vein, the adrenal, gonadal, and lumbar veins were ligated and divided with the LigaSure™ vessel-sealing device (Valleylab, Boulder, CO). An endoscopic TA linear stapling device was used to ligate the circumaortic renal vein at the point at which it coursed behind the aorta. Laparoscopic scissors were used to transect the vein lateral to the staple line. For a circumaortic renal vein, the adrenal, gonadal, and lumbar veins were similarly ligated and divided with the LigaSure™ vessel-sealing device. The smaller caliber retroaortic branch was identified, ligated medial to its bifurcation, and divided between Hem-o-lok clips.

At the time of allograft retrieval, each allograft was manually extracted in an effort to decrease warm ischemia time and to limit inadvertent injury to the harvested kidney.

In the recipient, the donor renal artery was anastomosed end-to-side to the recipient external iliac artery, and the donor renal vein end-to-side to the recipient external iliac vein. In the case of multiple renal arteries, the smaller artery (or arteries in the case of three renal arteries) was anastomosed end-to-side to the major renal artery on the back table, with a single arterial anastomosis in the recipient. In the case of multiple renal veins, both veins were separately anastomosed to the recipient iliac vein, unless there was a substantial size discrepancy, in which case the smaller renal vein was ligated.

Results

Donor demographic data, including age, gender, laterality of selected kidney, and laparoscopic technique employed, for 39 patients with complex renal vasculature who underwent LDN are listed in Table 1. There were 12 (31%) men and 27 (69%) women, with a mean age of 44.1 years (range 28–71 years). The left kidney was harvested in 37 (95%) cases and the right kidney in 2 (5%) cases. Of the 37 left LDNs, a conventional laparoscopic technique was employed in 24 (65%), and a hand-assisted technique was employed in 13 (35%). Both the right-sided LDNs were performed using a hand-assisted technique. Of the 39 donors, 19 (49%) were living related and 20 (51%) were living unrelated to the recipients. Four patients (10%) were rejected as potential renal donors at other transplant centers due to the presence of complex renal hilar vasculature.

The types of complex renal vasculature encountered are shown in Table 2. There were multiple renal arteries in 26 (67%) cases (double artery in 25, triple artery in 1) and multiple renal veins in 10 (26%) cases (double vein in 9, triple vein in 1). There were four (10%) cases with circumaortic renal veins, one (3%) with persistent left-sided IVC, and five (13%) with retroaortic renal veins. Thirty-four (87%) patients had a single anomaly, such as multiple vessels or anomalous renal vein anatomy, and five (13%) patients had multiple anomalies. These five cases included one case with a preaortic renal vein and two retroaortic renal veins, one case with a circumaortic renal vein and a persistent left-sided IVC, one case with a retroaortic renal vein and two renal arteries, and two cases with circumaortic renal veins and accessory renal veins (Table 2).

Table 3 contains information on donor outcomes. Mean operative time was 196.3 minutes (range 135–311 minutes),

Table 1. Donor Demographic Data

Donor characteristics	
Mean age	44.1 years
Gender	
Men	12 (31%)
Women	27 (69%)
Kidney harvested	
Left	37 (95%)
Conventional laparoscopic	24 (65%)
Hand-assisted	13 (35%)
Right	2 (5%)
Donor kidney	
Living related	19 (49%)
Living unrelated	20 (51%)
Donors rejected at other institutions	4 (10%)

Table 2. Complex Donor Renal Vasculature

Vascular anatomy	*Number*
Renal arteries	
Single artery	13
Double artery	25
Triple artery	1
Renal veins	
Single vein	27
Double vein	9
Triple vein	1
Venous anomalies	
Circumaortic renal vein	4
Persistent left-sided IVC	1
Retroaortic renal vein	5

IVC = inferior vena cava.

mean blood loss was 99.4 mL (range 25–400 mL), and mean hospital stay was 2.6 days (range 1–4 days). Donor creatinine preoperatively and at discharge was 0.8 mg/dL and 1.2 mg/dL, respectively. Mean warm ischemia time was 168.9 seconds (range 90–300 seconds). Three intraoperative complications occurred (7.7%), including an enterotomy at the time of wound closure that was closed primarily, a splenic laceration that was managed laparoscopically, and a stapler misfire on the renal vein that was laparoscopically sutured. No complications were caused by the presence of complex donor vasculature.

Recipient outcomes are shown in Table 4. Mean recipient age was 49.5 years (range 15–78 years). This was the first transplant in 35 (90%) recipients and the second transplant in four (10%) recipients. Mean recipient creatinine at the time of discharge was 1.45 mg/dL, and nadir creatinine at 1 and 2 years follow-up was 1.41 mg/dL and 1.30 mg/dL, respectively. There were two cases (5%) of graft failure. One case of hyperacute rejection required subsequent explantation on the fourteenth postoperative day. The other case of rejection was secondary to the return of the recipient's renal disease 21 months after transplantation. Two (5%) recipients expired due to nontransplant-related causes at 7 months and 19 months. Both allografts were functioning at the time of expiration.

Discussion

End-stage renal disease and the need for kidneys suitable for transplantation continues to be a major medical concern in the United States and worldwide. Since described by Ratner and colleagues in 1995, LDN has continued to gain acceptance for renal procurement as it offers low morbidity, shorter length of hospitalization, less pain medication requirements, and reduced convalescence as compared to open donor nephrectomy.[1]

Table 3. Donor Outcomes

Operative outcomes	
Mean operative time	196.3 minutes
Mean blood loss	99.4 mL
Mean warm ischemia time	168.9 seconds
Intraoperative complications	
Enterotomy	1
Splenic laceration	1
Stapler misfire on renal vein	1
Postoperative outcomes	
Mean hospital stay	2.6 days
Donor creatinine (preoperative)	0.8 mg/dL
Donor creatinine (at discharge)	1.2 mg/dL

Table 4. Recipient Outcomes

Mean age	49.5 years
Number of recipient transplant	
Primary	35 (90%)
Secondary	4 (10%)
Creatinine at discharge	1.45 mg/dL
Creatinine at 1 year	1.41 mg/dL
Creatinine at 2 years	1.30 mg/dL
Rejection	2 cases (5%)

Live donor nephrectomy in the setting of complex renal vasculature may be technically challenging. Such a procedure subjects the allograft to a longer warm ischemia time, requires extensive back-table reconstruction and more than a single vascular anastomosis in the recipient, and involves a potentially higher risk of segmental renal infarction following vascular reconstruction. Further, procurement of a kidney with complex vasculature adversely impacts operative time, warm ischemia time, and donor nadir creatinine, and adds to overall complications.[11,12,14–16] Kieran and Roberts reported that multiple donor renal vessels were not associated with significant differences in warm ischemia time or recipient graft function, although operative times were longer in patients with multiple renal arteries. They concluded that although LDN can be performed safely on kidneys with multiple renal arteries, increased operative time, associated patient risk, and higher overall cost may justify preferential selection of kidneys with single arteries.[17]

Such conclusions have been reexamined and challenged. Johnston and colleagues described their experience with 31 left donor kidneys with multiple vessels and reported similar results for warm ischemia time, operating time, and donor length of hospitalization for such patients.[15] They reported no significant difference in the incidence of acute tubular necrosis, graft survival, or follow-up serum creatinine in the recipients.

LDN was initially recommended solely for left renal units due to the presence of a longer renal vein and subsequent decreased risk of venous thrombosis as compared to the right renal unit. However, as the laparoscopic technique became more refined and surgeons gained experience, right-sided LDN was deemed feasible.[18] Additionally, procurement of left kidneys with multiple vessels or anomalous vasculature, previously thought to be inadvisable in a laparoscopic approach, has been attempted and reported in small series.[12,14–16,19] A hand-assisted approach has been advocated by some for patients with multiple renal arteries or retroaortic renal veins.[20,21]

At our institution, a conventional laparoscopic approach has been routinely used for LDN in patients with normal renal vasculature. However, in our early experience with complex vasculature, we used a hand-assisted approach to minimize inadvertent vascular injury and to maintain low operative times. As the volume of cases and comfort level increased, we transitioned to a conventional laparoscopic approach for all renal donors regardless of anatomy. At the time of allograft retrieval, the allograft is manually extracted to minimize warm ischemia time and to limit inadvertent injury to the harvested kidney.

In evaluating patients with complex vasculature it is important to diligently assess each individual's vascular anatomy to determine the proper trocar placement and make adjustments as necessary. Additionally, when performing LDN on donors with anomalous vessels, special consideration must be given to those vessels that must be spared until the moment of allograft extraction versus those that may be ligated earlier during the procedure.

Multiple arteries may be identified in as many as 27% of potential donors, and an attempt must be made to spare each accessory artery in addition to the main artery, especially lower-pole arteries, which also supply portions of the proximal ureter.[17] If additional veins are identified, small tributaries can often be ligated without consequence, while larger veins should be spared to provide better vascular drainage.

The manner in which accessory or anomalous vessels are ligated and transected must be taken into consideration prior to performing the procedure. Polymer hemostatic clips (Hem-o-lok clips) have been traditionally used to control arterial and venous vessels of varying sizes. We initially used these clips to control the adrenal, gonadal, and lumbar veins. However, our current practice is to use a bipolar vessel-sealing device for these venous tributaries. This device effectively seals and transects individual vessels and renders the renal vein free of clips that may interfere with the vascular stapling device at the time of renal vein ligation. In instances of circumaortic or retroaortic renal veins, the venous tributaries may also be anomalous or multiple. Ligation of these vessels must be carefully performed so as not to injure the main renal vein or interfere with later ligation and transection.

When dividing the main and accessory renal arteries, we initially placed two Hem-o-lok clips on each artery at its origin from the aorta, after which transection was performed lateral to the clips with laparoscopic scissors. Teleflex Medical, manufacturers of the Hem-o-lok clips, issued a memo in April 2006 stating that the Hem-o-lok ligating clips may become dislodged following ligation of the renal artery during LDN. As such, these clips are now contraindicated in ligating the renal artery during laparoscopic nephrectomies in living donor patients. Our current practice is to ligate each renal artery with an endoscopic TA linear stapling device at its origin from the aorta. The artery is immediately divided lateral to the staple line using laparoscopic scissors. If bleeding occurs through the staple line, a reinforcing clip is applied to the renal artery stump.

An endoscopic TA linear stapling device is also used to ligate the main and accessory renal veins medial to the insertion of the adrenal and gonadal branches. This stapler places three rows of staples proximally on the vessel and does not divide the vessel. Laparoscopic scissors are used to divide the vessel lateral to the staple line such that no staples are left on the allograft portion of the renal vein. In this method, no staples require excision prior to transplantation, which would further decrease the vessel length. The major disadvantage of the endoscopic TA stapler is that it does not articulate. When an adequate length of the renal artery or vein is likely to be compromised due to the inability of the TA stapler to achieve an appropriate angle, an endoscopic roticulating GIA stapler may be used. However, this stapler places six rows of staples, dividing the vessel between rows 3 and 4, thereby leaving three rows of staples that must be excised from the allograft vessel.

Circumaortic and retroaortic variants constitute the most common anomalies of the left renal vein, with a reported incidence of 9% to 14%.[16] Because of the higher risk of vascular injury and hemorrhage, the presence of a circumaortic or retroaortic renal vein has previously been considered a relative contraindication for left donor nephrectomy by some surgeons.[11] However, Lin et al and others have reported that parameters such as operative time, warm ischemia time, length of allograft vessels, and estimated blood loss were similar regardless of whether a circumaortic or retroaortic renal vein was present.[11,16]

A retroaortic renal vein typically courses posterior to the aorta from a caudal location toward the renal hilum. In this situation, the renal artery is often identified in a more cephalad location, rather than immediately posterior to the renal vein. The insertion of the adrenal, gonadal, and lumbar veins may enter the renal vein in an abnormal fashion. In the case of a circumaortic renal vein, the retroaortic portion is usually smaller in caliber then the anteroaortic portion. The retroaortic branch can then be safely ligated medial to the point where the anteroaortic and retroaortic portions join. In this manner, the proximal venous return is diverted to the anteroaortic branch of the renal vein. Also, gonadal veins may be multiple and the insertion may be in an abnormal location along the anteroaortic or retroaortic portions of the vein. Careful examination of preoperative radiographic imaging is mandatory in the proper diagnosis of such anomalies. Additionally, meticulous hilar dissection and awareness of potential variation in vascular anatomy are of paramount importance.

In a recent study by Fettouh, outcomes of LDN in 79 patients with vascular anomalies were compared to outcomes in 321 donors with normal vascular anatomy.[19] The only statistically significant difference between the two groups was operative time (161 minutes for vascular anomalies versus 131 minutes for normal vascular anatomy). One-year graft survival for allografts with vascular anomalies was 93.4%, which translates to 74 of 79 functioning transplants at 1 year. This was not statistically different from the 94% 1-year graft survival observed in allografts without vascular anomalies.

We have been following all donors and recipients and have accumulated intermediate data for patients with 2-year follow-up. Our results similarly demonstrate that complex renal vasculature is not a contraindication to LDN. Our 1- and 2-year graft survival for allografts with complex vasculature was 97.4% and 94.6%, respectively. Of note, four (10%) patients who underwent successful LDN at our institution were previously rejected as potential renal donors at other transplant centers due to the presence of complex renal hilar vasculature.

Conclusion

Complex renal hilar vasculature can be present in up to 30% of potential renal donors, a finding that may preclude a candidate from donation at certain medical centers. LDN in cases of multiple vessels or anomalous venous vasculature is safe for both the donor and the recipient, with similar outcomes compared to those with normal vasculature. Including patients with complex vasculature as viable renal donors may increase the availability of allografts. These cases require thorough preoperative imaging and awareness of potential vascular variants to ensure precise intraoperative dissection with maximal vascular preservation.

Disclosure Statement

No competing financial interests exist.

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Abbreviations Used

CT = computed tomography
IVC = inferior vena cava
LDN = laparoscopic donor nephrectomy