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There continues to be a growing disparity between organ supply and demand. Because the supply of cadaver kidneys has remained relatively fixed, alternative sources of organs, including ways to increase live organs, have been sought. In February 1995, Ratner and colleagues performed the first successful laparoscopic live-donor nephrectomy (LLDN). Since then, the authors and others have noted an increase in live-kidney donation. It has been shown that LLDN offers the donors shorter recuperative time, less postoperative pain, improved cosmesis, similar hospital costs, and currently similar or less morbidity compared to open nephrectomy. The reduction in donor financial burden postoperatively as a result of earlier return to work is another incentive for the donors. In addition, it has been shown that the recipients have at least similar patient and graft survival rates, short- and long-term renal functions, frequency and severity of rejection episodes, need for dialysis, costs, and readmission rates compared to recipients with kidneys procured from the standard open-nephrectomy operation. The authors conclude that LLDN should be the standard practice for live kidney donors.

Introduction

Since the first successful renal transplant in 1954, clinical renal transplantation has evolved from a nearly hopeless procedure to a highly effective operation. Renal transplantation is the treatment of choice for patients with end-stage renal disease. As of May 3, 2002, there were 54,944 patients in the United States awaiting renal transplantation, but only 14,152 kidney alone transplants (5293 were living donors) were performed in 2001.[1] A disparity continues to grow between the organ supply and demand, and waiting time has increased. The waiting list for kidneys increased by approximately 8.5% from 1999 to 2000, whereas the number of transplants performed increased only by about 6.5% during this same period, despite the advent of increasing living donor transplantation. Transplants from cadaver kidney donors increased by only 0.7% for the same period of time. The primary increase in recent kidney transplants has come from volunteer living donors; these donors account for 22% in 1990 up to 39.5% in 2000. At our institutions, recipients of live-donor kidneys usually receive kidneys within 2 to 3 months of initial evaluation, as opposed to the 2- to 6-year waiting period for a cadaver donor kidney. Because the supply of cadaver kidneys has remained relatively fixed, alternative sources of organs, including ways to increase live organs, have been sought.

Live-Donor Renal Transplantation

Live-donor renal transplantation, when compared to cadaver renal transplantation, has several advantages, including shorter waiting time, lower incidence of delayed function, improved graft and patient survival, shorter hospitalization time, and lower cost.[2-5] Reasons include shorter cold ischemic and elective waiting time, earlier resumption of renal function, and better immunologic compatibility, especially if donor and recipient pairs are relat-

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ed. The graft and patient survival rates for recipient of cadaver donor kidneys are currently 92% and 95.5% at 1 year and 66% and 82.5% at 5 years, respectively.[1] In contrast, the living donor graft and patient survival rates are 96% and 98% at 1 year and 79% and 91% at 5 years, respectively. Despite the advantages of living donor renal transplantation, there exist significant disincentives that include prolonged recuperative time, pain, and cosmetic results.[6] It is unknown how many patients have been denied a live-donor renal transplant because financial and logistical disincentives imposed by the open-donor operation were too great for the potential donor. Many of these patients continue prolonged dialysis or undergo marginal cadaver renal transplants with suboptimal results. Donors are frequently asked to make personal sacrifices and time commitment. The relatively prolonged convalescence can have a significant financial impact on the donor. In addition, the natural fear of pain, as well as cosmesis associated with a traditional flank incision, can militate against kidney donation.

Laparoscopic Live-Donor Nephrectomy

Laparoscopic nephrectomy was first proposed in 1990 for removing diseased kidneys.[7] Several subsequent studies have demonstrated the marked decrease in postoperative pain, shorter convalescence, and improved cosmetic results achieved compared to traditional open nephrectomy.[8-10] In February 1995, Ratner et al.[11] performed the first successful clinical laparoscopic live-donor nephrectomy (LLDN). LLDN was only first attempted in humans after Gill et al.[12] demonstrated in a porcine model that adequate vascular length could be obtained on a consistent basis. We hypothesized that if we decreased donor morbidity by the application of minimally invasive laparoscopic techniques that included high-quality video systems and vascular stapling devices to the donor operation, then perhaps more individuals would be willing to donate their kidneys. However, the increase in the willingness to donate should be based on objective data that the renal transplant recipient with laparoscopically procured kidneys have at least similar patient and graft survival rates, short- and long-term renal functions, frequency and severity of rejection episodes, need for dialysis, costs, and readmission rates compared to recipients with kidneys procured from the standard open-nephrectomy technique. Most important, the healthy altruistic donor should suffer no mortality and have a morbidity rate that is similar to or less than that of donors who undergo the conventional open-nephrectomy technique. We have previously presented data in several reviews that kidneys procured through LLDN satisfied the above criteria.[13-24] In addition, LLDN offers the donors shorter recuperative time (earlier return to work and full activities), less postoperative pain, and improved cosmesis.

Donor Evaluation

The only relative contraindication for the laparoscopic operation that does not exist for the open-donor operation is a history of extensive upper abdominal surgery that would likely result in dense adhesions, rendering laparoscopic access unsafe. However, since performing LLDN at Johns Hopkins medical institutions in 1995 and currently at our respective institutions, we have not excluded any individual from undergoing LLDN who would not have been excluded from donating via the standard open approach. We have operated on more than 10 donors older than 60, the oldest being 74 years old. The patient evaluation for LLDN is similar to that employed for the open-donor operation, and guidelines have been published.[25]

Obesity is not a contraindication to LLDN. The largest individual we have operated on so far weighed about 290 lb. Kuo et al.[26] recently demonstrated that in obese donors (n = 12) (mean body mass index of 34) versus nonobese donors (n = 28), there was no increase in technical complications or incidence of open conversion. Similarly, in a study on anatomic, demographic, and radiologic parameters that might influence operative difficulty, we found that although increasing patient weight correlated with longer operative times (r = 0.50, P = 0.002), the increase did not have any effect on the technical difficulty of the laparoscopic operation (r = 0.10, P = 0.51).[27] In fact, none of the measured anatomic, demographic, or radiologic parameters were predictive of operative difficulty for LLDN. In addition, we and others have shown that multiple renal arteries and aberrant vascular anatomy are also not a contraindication to LLDN, with both

donor and transplant recipients showing a similar outcome with the traditional open technique.[28-30] This procedure has been performed on donors with as many as 4 renal arteries.[29]

We routinely obtain a dual-phase spiral 3-dimensional (3D) computed tomography (CT) angiogram for use as an anatomic roadmap.[31] Spiral 3D CT angiography has been shown to have an accuracy comparable to that of conventional angiography in defining renal arterial anatomy. It is better at mapping venous anatomy in terms of location, size, and length, and provides additional information with regard to abdominal organs and their relationship to the kidneys. In addition, spiral 3D CT is associated with no significant morbidity to the donor.

Techniques

We have performed more than 450 laparoscopic donor nephrectomies combined, and the operations have previously been described in detail in multiple reviews.[11,16,24,31,32] Patient positioning and laparoscopic port placements for left LLDN are depicted in Figure 1. The incisions include a 0.5 cm subxiphoid port, two 1.2 cm infraumbilical and left lateral rectus ports, and a 5 cm Pfannenstiel's incision for atraumatic delivery of the kidney.

LLDN is more difficult on the right side due to the shorter renal vein and the need to retract the liver to provide adequate exposure. Currently, when the right kidney must be taken, the donor operation is modified as previously described.[16,28,32-34] Dissection is performed laparoscopically, but the kidney is delivered through a 6 cm right upper quadrant transverse incision. This allows for open cross-clamping of the inferior vena cava and division of the renal vein with a cuff of vena cava. However, in obese individuals it is difficult to obtain adequate exposure via a 6 cm transverse incision. Alternatively, the right renal vein can be divided in the usual fashion with the endovascular gastrointestinal anastomosis (GIA) stapler and reconstructed on the back table with a panel graft of recipient saphenous vein. It has been our practice to use the left kidney, even if there are multiple renal arteries or venous anomalies such as retroaortic or circumaortic left renal veins, rather than contend with the problem of a short, thin right renal vein.

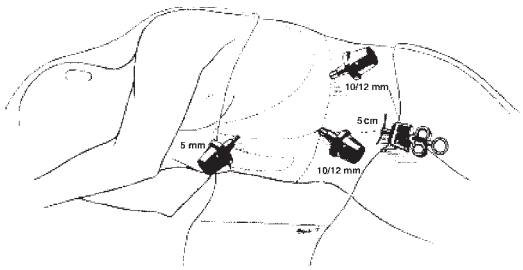

Figure 1. Laparoscopic donor left nephrectomy. The 3 port placements (10/12 mm and 5 mm) are noted. The 4th port is placed in the midline through a Pfannenstiel's incision less than 2 in. in length.

Donor Postoperative Course

We surveyed the major concerns expressed by live kidney donors.[35] The most common concerns are the effect of donation on future health, time out of work, the ability to return to the previous activities, and postoperative pain. We therefore advocate that LLDN be the standard of care because it can reduce these concerns compared to traditional open nephrectomy. Nowhere in surgical practice are the benefits of laparoscopic surgery more appreciated than in the removal of a normal organ from a healthy patient, as in LLDN.

In our earlier published series, patients who underwent LLDN compared to the open-flank approach resumed full activities (2.2 ± 0.8 weeks vs. 4.2 ± 2.4 weeks) and returned to employment sooner (3.9 ± 1.8 weeks vs. 6.4 ± 3.1 weeks).[35-37] The donor postoperative course and functional recuperation are listed in Tables 1 and 2, respectively. In the subset of patients that performed physically demanding jobs, the laparoscopic cohort reported that they felt able to return to work significantly sooner than the open group (3.8 ± 2.7 weeks vs. 8.0 ± 4.0 weeks, $P = 0.019$).[38] The length of hospitalization was also significantly shorter for the patients who underwent the laparoscopic operation (2.9 ± 1.0 days vs. 5.5 ± 1.2 days). In addition, the postoperative analgesic requirements, complications, readmission rates, and estimated blood loss were significantly lower in the laparoscopic group. After discharge, durations of oral analgesic requirements were significantly decreased for both prescription narcotics and subsequent over-the-counter preparations with the laparoscopic operation.[38] Similar re-

Table 1 | **Donor Postoperative Course**

Criterion	Open ($n = 20$)	Laparoscopic ($n = 19$)	*P* Value
Oral intake resumed (days ± *SD*)	2.5 ± 1.0	0.8 ± 0.4	< 0.001
Length of stay (days ± *SD*)	5.7 ± 1.7	3.1 ± 1.2	< 0.001
Analgesic (mg intravenous morphine ± *SD*)	124 ± 88	34 ± 34	< 0.001
Full activity resumed (weeks ± *SD*)	4.2 ± 2.4	2.2 ± 0.8	0.008
Returned to work (weeks ± *SD*)	6.4 ± 3.1	3.9 ± 1.8	0.01

Table 2 | **Donor Functional Recuperation**

Functional Parameter	Open ($n = 37$)	Laparoscopic ($n = 25$)	*P* Value
Length of hospitalization (days ± *SD*)	5.5 ± 1.2	2.9 ± 1.0	< 0.001
Able to return to work (weeks ± *SD*)	6.2 ± 3.2	3.2 ± 2.1	< 0.001
Actual return to work (weeks ± *SD*)	6.3 ± 3.3	4.4 ± 2.7	0.02
Resumed driving (days ± *SD*)	22.2 ± 17.0	13.5 ± 10.8	0.01
Resumed exercising (days ± *SD*)	65.8 ± 58.2	25.2 ± 27.0	0.003
Caring for the home (days ± *SD*)	31.7 ± 3.3	12.7 ± 10.7	< 0.001

sults have been published by the University of Maryland,[39] Georgetown University,[40,41] the University of Rochester,[41] Tulane University,[42] and the University of Louvain in Belgium and Geneva University Hospital in Switzerland.[43] Blood loss, length of stay, parenteral narcotic requirements, time until resumption of diet, time until return to normal activity, and time out of work were significantly less in the laparoscopic group. Table 3 summarizes the results of comparative reports of LLDN versus open-donor nephrectomy, including a randomized controlled study with hand-assisted laparoscopic donor nephrectomy. Recently, Kuo et al.[41] reported that 88% of their LLDNs were discharged within 23 h without incurring additional complications or donor dissatisfaction.

Donor Morbidity and Mortality

Mortality associated with the standard open nephrectomy is estimated to be about 0.03%.[17,25] Currently, there has been no mortality in more than 300 LLDNs performed at the University of Rochester, Johns Hopkins University, and Thomas Jefferson University. In the 1st 175 LLDNs at Johns Hopkins, donor morbidity has been acceptable.[48] Only 16 right-sided donor nephrectomies were performed during this period. The average blood loss was 304 mL. The overall complication rate in the laparoscopic group was 22 (12.6%) patients (Table 4). There were 3 intraoperative open conversions (1.7%): a defective endovascular GIA staple malfunctioned on the proximal end of the renal artery, an atherosclerotic plaque ruptured during ligation, and an anterior branch to the renal vein was torn during dissection. A total of 6 (3.4%) patients required blood transfusion: the 3 patients who required open conversions for bleeding, 2 (1.1%) patients who had postoperative retroperitoneal bleed, and 1 patient who had epigastric artery bleed from trocar injury. There were a total of 10 (5.7%) patients with the following major complications: proximal ureteral transection requiring the use of native ureter in the recipient (1), postoperative retroperitoneal bleeding requiring transfusion (2), endovascular GIA malfunction (1), reoperation for an epigastric artery injury (1), left upper lobe pneumonia requiring antibiotics (1), incisional hernia in a patient with previous abdominal surgery (1), and trocar-related bowel injury recognized intraoperatively and repaired through the 5 cm kidney retrieval incision (1). There was no short- or long-term morbidity for either the donor or the recipient. Minor complications occurred in a total of 12 patients (6.9%), with some of the patients having 1 or more of these minor complications: transient thigh paresthesia (7), mucus plug or atelecta-

Table 3 | **Results of Laparoscopic, Hand-Assisted Laparoscopic, and Open Live-Donor Nephrectomies**

	Ratner et al.[28]	Flowers et al.[39]	Koffron et al.[44]	Brown et al.[45]	Wolf et al.[46,a]	Hawasli et al.[47,b]	
Patients, *n*							
Laparoscopic	323	70	70	80	50	23	30
Open	241	20	65	50	50	27	29
Operative time, (min ± *SD*)							
Laparoscopic	230 ± 29	225.3	276	234	206 ± 32	181	
Open	183 ± 47	212.8	186	208	125 ± 36	150	
P value	< 0.001	*ns*	< 0.05	0.0068	< 0.0001		
Estimated blood loss (mL ± *SD*)							
Laparoscopic	266 ± 174	122.3	165	114	156 ± 148	125	
Open	393 ± 335	408.0	174	193	216 ± 280		
P value	0.027	0.0001	*ns*	0.0001	0.91		
Parental analgesia							
Laparoscopic	40 ± 33 mg morphine sulfate	28.6 h	17.2 h		59 ± 62 mg morphine sulfate		
Open	124 ± 88 mg morphine sulfate	60.1 h	38.3 h		111 ± 96 mg morphine sulfate		
P value	< 0.001	0.0001			0.004		
Length of stay (days ± *SD*)							
Laparoscopic	3.0 ± 0.9	2.2	2.1	3.5	1.7 ± 0.9	1.3	
Open	5.7 ± 1.7	4.5	3.2	4.7	2.6 ± 0.7	4.1	
P value	< 0.001	0.0001	< 0.05	0.0001	0.0001	< 0.0001	
Resume oral intake (h ± *SD*)							
Laparoscopic	19.2 ± 12	16.3	8.1		20 ± 14		
Open	62.4 ± 24	51.0	20.9		21 ± 10		
P value	< 0.001	0.0001	< 0.05		0.57		
Resume full activity (weeks ± *SD*)							
Laparoscopic	1.7 ± 1.2						
Open	4.1 ± 2.4						
P value	< 0.001						
Resume employment (days ± *SD*)							
Laparoscopic	28 ± 16.1	15.9				14.8	
Open	44.8 ± 21.7	51.5				28.4	
P value	0.003	0.0001				< 0.01	

a. Randomized control with hand-assisted laparoscopic nephrectomies.
b. Community transplant program.

sis (1), superficial wound infections (5), urinary tract infections (2), epididymitis (1), and postoperative ileus requiring readmission for bowel rest (1). Of note, complications that are not uncommon with the open-donor operation such as pneumothorax, incisional hernia, diastasis, and chronic wound pain or discomfort are virtually nonexistent with the laparoscopic operation. There was no small-bowel obstruction or splenectomy in our series. However, 2 such cases have been reported in which a small-bowel obstruction resulted from an internal hernia in the retroperitoneum[49] and a loop of small bowel became entangled in the midline fascial closure.[50]

The University of Wisconsin reported an overall complication rate of 17% in a retrospective 20-year review of 681 live-donor open-nephrectomy patients.[51] The University of Minnesota published an overall complication rate of 8.2% in 871 live-donor open-nephrectomies.[52] Two patients sustained femoral nerve compression with resulting weakness, and 1 patient required reexploration for a retained sponge. The minor complication rate was estimated to be 8%. In 66 (7.6%) cases, there was recognized pleural entry. Postoperatively, 13 pneumothoraces were found and 6 (1.5%) patients required chest tube placement. Wound infections occurred in 2.4% of patients. In 109 (12.5%) donors,

Table 4 | **Mortality and Morbidity Rates for the 1st 175 Laparoscopic Live-Donor Nephrectomies at the Johns Hopkins Medical Institutions**

	n	%
Mortality	0	0
Patients with 1 or more morbidities	22	12.6
Patients requiring blood transfusions	6	3.4
Patients with major morbidities	10	5.7
Postoperative retroperitoneal bleed requiring blood transfusion (2)		
Proximal ureteral transection (1)		
Open conversions for bleeding requiring blood transfusions		
Endovascular gastrointestinal anastomosis malfunction (1)		
Atherosclerotic plaque ruptured during ligation of renal artery (1)		
Anterior branch of the renal vein torn during dissection (1)		
Trocar-related bowel injury repaired laparoscopically (1)		
Reoperation for epigastric artery bleed requiring blood transfusion (1)		
Pneumonia (1)		
Incisional hernia (1)		
Total number of patients with 1 or more of the following minor morbidities	12	6.9
Transient anterior thigh paresthesia (7)		
Mucus plug or atelectasis (1)		
Superficial wound infection (5)		
Urinary tract infection (2)		
Epididymitis (1)		
Ileus (1)		

there was inadvertent entry into the peritoneum; only 1 enterotomy was sustained intraoperatively. A recent multi-institutional review of 3657 open procedures with up to a 28-year follow-up revealed a 16% overall complication rate, ranging from 8% to 47%.[17] In these series, mortality was 0.03%, estimated blood loss was 250 to 300 mL, and mean operative time was approximately 4 h. There was a mean postoperative stay of 5 days (range = 4-14). Morbidity rates in LLDN appear to be equivalent to historic open series. Conversion rates in our LLDN series were 1.7% and were related to bleeding or the learning curve related to laparoscopy. Definition of complications varies between series, and types of complications differ between laparoscopic and open approaches. Regardless, complications in live-donor nephrectomy can be significant whether it be laparoscopic or open surgery. We believe, as with open nephrectomy and with other laparoscopic operations, as experiences increase, one would expect complications to decrease.

The University of Maryland published similar laparoscopic donor nephrectomies results.[39] Morbidity in their series was 14% in the laparoscopic group and 35% in the open group. Likewise, in the Georgetown University series of 40 LLDN, there was a 5% conversion rate and a 2.5% incidence of urinary tract infection.[40] Recently, Kuo et al.[41] at Georgetown University reported that with adequate preoperative teaching and preparation, and a standardized anesthetic and analgesic protocol, 88% of their patients have been discharged from the hospital within 23 h of surgery. Importantly, none of the 41 patients enrolled in the 23-h protocol expressed dissatisfaction with the procedure or subsequent postoperative care.

Recipient Outcome and Graft Survival

The recipient and graft survival and outcomes are as important as the safety of the donor. Leow,[53] Novick,[54] Serota,[55] and Barry[56] questioned whether the benefits of the donor are offset by poor allograft function, recipient morbidity, and, therefore, protracted recipient length of stay. A concern is whether elevated intra-abdominal pressure associated with pneumoperitoneum might result in renal ischemia, acute tubular necrosis, and delayed graft function, and may render the organ more allogenic

Table 5 | **Kidney Transplant Recipients and Graft Survival Morbidity, Early and Late Renal Function, and Hospital Stay**

	Open ($n = 48$)	Laparoscopic ($n = 110$)	*P* Value
Recipient survival (1 year), %	100	97.0	*ns*
Graft survival (1 year), %	93.5	91.1	*ns*
Ureteral complications, *n* (%)	3 (6.3)	1 (2.1)	*ns*
Urine leak	2 (4.2)	10 (9.1)	*ns*
Ureteral stenosis	7 (6.4)	3 (2.7)	*ns*
Vascular thromboses, *n* (%)	2 (4.2)	3 (2.7)	*ns*
Serum creatinine on postoperative day no. 4 (mg/dL)	2.0	2.8	*ns*
Requiring dialysis the 1st week, *n* (%)	3 (6.3)	7 (6.4)	*ns*
Acute rejection within 30 days, *n* (%)	15 (31.9)	32 (30.1)	*ns*
Acute rejection within 90 days, *n* (%)	17 (35.4)	33 (30)	*ns*
Creatinine clearance at 1 year (mL/min)	66	66	*ns*
Creatinine clearance at 2 years (mL/min ± *SD*)	63.3 ± 19.5	74.7 ± 27.2	*ns*
Recipient hospital stay (median days)	7	7	*ns*

in the recipient. Additionally, concerns have been expressed that the laparoscopic technique might yield organs with inadequate lengths of vessels and/or ureter, or could result in injury to these structures, thus increasing the recipient's risk for technical complications.

We recently conducted a detailed analysis of the transplant recipients of laparoscopically procured kidneys performed from January 1995 through April 1998.[14,57] A total of 110 patients received kidneys from laparoscopic and 48 from open donors. No significant differences were observed in transplant recipients for graft survival, incidence of technical complications (ureteral or vascular), serum creatinine on postoperative day 4, need for dialysis, incidence, timing or severity of acute rejection episodes,[21] long-term creatinine clearance, or hospital stay (Table 5). Although recipients of donor kidneys obtained via open surgery initially tended to have lower serum creatinine levels than did patients whose grafts were procured via a laparoscopic approach, by postoperative day 4 or 7 there was no significant difference between the 2 groups. The creatinine clearance at 1 or 2 years was identical between the 2 groups. These results suggest that concerns of a potential increased incidence in delayed graft function or graft allogenicity caused by increased warm ischemia time because of extraction of the kidney and decreased renal perfusion as the result of pneumoperitoneum have not been substantiated. This was affirmed with long-term follow-up.[13] Warm ischemia time has been short (generally less than 5 min).

London et al.[58] demonstrated that the deleterious effect of pneumoperitoneum and elevated intra-abdominal pressure on renal function can be negated by volume loading. It is not uncommon for our laparoscopic donors to receive 8 to 10 L of crystalloid intraoperatively to promote a brisk diuresis. However, it is unclear whether the use of hypertonic saline for volume loading may be more beneficial.

Currently, the 1-year transplant recipient and graft survival rates for our 2nd set of 100 patients (i.e., case 101st to 200th) are 98% and 96%, respectively (death assumes graft failure). Similar results have been reported from the University of Maryland,[30,59] Georgetown University,[30,40] Washington Hospital Center,[60] the University of California, Davis,[50,61] Mount Sinai Hospital,[62] Hennepin County Medical Center and Abbott Northwestern Medical Center,[63] Tulane University,[64] Belgium,[43] Switzerland,[43,62] and Australia.[65] However, it is important to note that a prospective randomized trial of LLDN versus open nephrectomy has yet to be performed. Unfortunately, it will be difficult to conduct a randomized prospective trial, as we and others[41,60,63] could not get any patient to sign up for the alternative, open nephrectomy. Recently, the

University of Michigan demonstrated that in a small nonrandomized but prospective study (n = 10) comparing hand-assisted laparoscopic to open-donor nephrectomies, initial allograft function appears to be similar.[66] The patients' morbidity was also similar to the standard LLDN and significantly less than that of open nephrectomies. A latter randomized controlled trial of 60 patients (see Table 4) demonstrated that the hand-assisted laparoscopic donor nephrectomy group is associated with a briefer, less intense, and more complete convalescence compared with the open surgical group.[46]

The LLDN has evolved over the past 6 years, and several important lessons have been learned. The effect of a "learning curve" was noted in the laparoscopic group with regard to the technical complications.[19] All (3) vascular thromboses were observed prior to modification of the laparoscopic donor operation for right kidneys. This learning curve is not unique to this operation and was encountered when the laparoscopic cholecystectomy was introduced.[67]

In our series, urine leaks were treated operatively in all cases. Ureteral stenoses were treated nonoperatively with percutaneous stents. No grafts were lost due to ureteral complications. The majority of ureteral complications in the laparoscopic cohort occurred early after we began using the Endocatch bag to deliver the kidney instead of manual extraction as initially described,[11] and these cluster between cases 33 and 70. We learned that it is imperative for the allograft ureter to be completely within the bag before tightening the purse string to avoid stripping its vascular supply. Additionally, at case 50 we began training a 2nd generation of surgeons (including residents and fellows). It became apparent that it is quite easy to dissect too close to the renal pelvis and that the safest way to avoid devascularizing the ureter is to mobilize it with the gonadal vein in a plane medial to the gonadal vein.[16] The ureter and periureteral tissues are transected with a endovascular GIA. We have also adopted a very low threshold for placing an indwelling stent in the allograft ureter at the time of ureteroneocystostomy. Since implementing this technical change in our last 180 LLDNs, our donors have not sustained any postoperative ureteral injuries. A sharp reduction in ureteral injury to near nonexistence was also seen in the latest series of LLDNs from the University of Maryland when this technique was adopted.[68-70]

Financial Analysis and Impact on Live Donation

There are 3 areas where LLDN has a financial impact: (1) the total cost of hospitalization including the operation; (2) the financial burden that the donor has to accept in terms of time out of work, an expense that may not be covered by Medicare; and (3) the overall financial impact of increasing live-kidney donation and the associated savings achieved with transplantation compared to long-term dialysis.

LLDN does not result in any cost savings for the operative hospitalization. In a retrospective cross-sectional multivariate regression analysis performed on 71 laparoscopic and 71 open-donor nephrectomies, we found that there was no significant difference in unadjusted and adjusted (Table 6).[71] Although laparoscopic supplies were almost 3 times as expensive as open supplies ($2251 vs. $812, $P < 0.001$), there was no overall difference in total hospital charges between groups. The University of Maryland also substantiated this.[72] In addition, the complication rates and readmission rates were lower for the laparoscopic compared to the open procedures (10.9% vs. 25.0% [$P < 0.05$] and 3.1% vs. 7.6% [$P = ns$], respectively). Use of nondisposable instruments and further reduction in hospitalization may further reduce perioperative costs.[41]

Reduction in donor financial burden by decreasing recuperative time is one of the main goals of LLDN. Recently, 3 groups have demonstrated a reduction in donors' loss of income with LLDNs. Wolf et al.[66] reported that loss of donors' occupational income was 11% less in the laparoscopic group, and Odland et al.[63] reported that the financial loss per donor was only $783 ± $500 following LLDNs as opposed to $2626 ± $2000 ($P < 0.05$) for the open donors. Mackey et al.[72] examined 29 LLDN patients and compared them to a group undergoing open donation. The authors assessed actual cost to employers while employees were out of work recuperating from surgery. The groups were matched based on age, socioeconomic status, and type of employment. The patients who underwent laparoscopic donation returned to work on average 25 days sooner than did those undergoing open do-

Table 6 | **UNADJUSTED TOTAL HOSPITAL COST PER DONOR (IN US$)**

SPECIFIC COST	OPEN ($n = 71$)	LAPAROSCOPIC ($n = 71$)	*P* Value
Hospital room and routine charges	2411	1774	< 0.001
Operating room charges	1443	1610	< 0.01
Supplies	812	2251	< 0.001
Pharmacy	252	204	< 0.05
Labs	240	183	< 0.01
Radiology	137	44	< 0.01
Respiratory therapy	25	19	*ns*
Other miscellaneous	303	426	< 0.001
Total (unadjusted)	5623	6511	*ns*

nation. The calculated actual cost savings to employers exceeded $4000 per employee.

Live-donor renal transplantation is more cost-effective than either cadaver transplantation or dialysis.[2] Schweitzer et al.[3] calculated that for an uncomplicated live-donor renal transplant the "break even" point with dialysis is now only 1.7 years. Since the inception of our LLDN programs, we have realized a greater than 3-fold increase in live donation. Also, two-thirds of the individuals donating at our centers stated that the availability of the LLDN influenced their decision whether to donate. Similar increases in live donation have been observed at other transplant centers (the University of Florida,[41] the University of Maryland,[73] Georgetown University,[40,41] Tulane University,[42,64] the University of California at Davis, Temple University, and the Medical University of South Carolina). One-fifth of patients reported that they would not have donated if the open operation had been their only option, and two-thirds of patients reported that the availability of the laparoscopic operation profoundly influenced their decision to donate. At the University of Maryland, live-donor kidneys increased from 25% of the kidney supply to 40%.[73] Kuo and Johnson[40] reported that 47% of LLDN donors donated solely because of the availability of the LLDN procedure and would not have otherwise donated. Furthermore, 58% of LLDN donors were unrelated, indicating an increased supply of living renal donors with implementation of LLDN. Kuo and Johnson's data also imply that LLDN transplant centers attract prospective donors away from centers not performing LLDNs.

Thus, we demonstrate that by removing disincentives to live donation, LLDNs can increase the supply of living donor kidneys. Recently, using a composite index of donor "cost" for this act of altruism, Kuo and Johnson[40] demonstrated that LLDN has shifted the supply function of living donor kidneys and, as a result, has increased the number of living donor renal transplants in a center-specific fashion. Finelli et al.[74] surveyed the 31 highest volume kidney transplant centers in the United States and found that 39% of centers performed LLDN in 1998, increasing to 65% in 1999. Six-month follow-up interviews found that 84% of centers had performed LLDN. In addition, the issue of disincentives to live donation is now receiving greater scrutiny. Previously, it was thought that all donors were highly motivated to donate. However, studies performed at our center[35] have demonstrated that a number of social and financial factors that can be addressed will influence individuals' willingness to donate. We[75] and others[76] advocate that alternate strategies be explored to further encourage live-kidney donation. Such strategies might include making available disability insurance, reimbursement for out-of-pocket expenses, and child care. Significant savings are achieved with live-donor renal transplantation compared to cadaver donor transplantation. We propose that a portion of these savings be allocated for these goals. Federal legislation is now being considered that would provide for live donors' travel expenses. The Southeastern Organ Procurement Foundation is establishing a program to provide low-cost insurance for organ donors. Also, we are now seeing an increasing number of in-

dividuals who are wishing to donate kidneys to strangers for purely altruistic reasons at our institution.

Summary

In conclusion, the operation laparoscopic live-donor nephrectomy (LLDN) is technically feasible with a learning curve and is now routinely performed even in community transplant programs, with minimal morbidity (or complications) similar to that of the standard open donor nephrectomy technique. To our knowledge, there is no mortality associated with the estimated 1000 LLDNs performed worldwide. In addition, the operation has evolved significantly over the past 6 years, and the modified operation that is performed today is vastly improved compared to that originally described in 1995. We and many others have demonstrated that LLDN compared to the standard open operation offers donors several important advantages including decreased postoperative pain, shorter hospitalization, quicker recuperation and return to normal activities and employment, smaller incisional scar, and cosmesis. This has resulted in less lost wages and a lower financial burden for donors to bare. In addition, this has been achieved with minimal warm ischemia time with similar recipient survival, similar immediate and late graft function and survival, and no additional or laparoscopy-specific morbidity compared to open-donor nephrectomy. There is also no increase in technical complications, and recipient length of hospitalization is unaffected. The kidney is removed atraumatically, an adequate length of vascularized ureter is preserved, and adequate length of renal artery and vein without endothelial or intramural damage is preserved, with a low rate of vascular and ureteral complications. It is cost-effective, and total hospital charges (including operating rooms and hospital rooms charges) are similar ($P > 0.05$). We and many others have seen and reported that the laparoscopic operation has been effective in increasing individuals' willingness to donate by removing many disincentives to live-kidney donation. We have also seen an increase in altruistic individuals who have come forward to donate their kidneys to the most suitable recipient. The increase seen in live-donor transplantation will most likely result in long-term cost savings. This operation has now been performed successfully in more than 100 transplant centers on 5 continents. Similar results have been obtained by community hospital transplant centers[47] and groups outside the United States, including Australia,[65] the Netherlands,[77] Belgium,[43,78] Switzerland,[43,62] Sweden,[79] and India.[80] The results obtained thus far from LLDN have been demonstrated to be at least comparable with the results of the gold standard open-donor nephrectomy. In addition, LLDN provides many advantages to the donor. The LLDN should now be considered the new standard of care by which kidneys are procured for renal transplantation. As with any other procedure, we should continue to refine the LLDN operation to further minimize morbidity.

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