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ORIGINAL ARTICLE

Standardized video-assisted retroperitoneal minilaparotomy surgery for 615 living donor nephrectomies

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laparotomy, live donor, minimally invasive surgical procedures, nephrectomy, retroperitoneal space.

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Summary

To increase the rate of living kidney donation, the long-term safety of nephrectomy must be demonstrated to potential donors. We analyzed long-term donor outcomes and evaluated the standardization of surgical technique. We evaluated 615 donors who underwent Video-assisted minilaparotomy living donor nephrectomy (VLDN) at Yonsei Severance Hospital between 2003 and 2009. Perioperative data and predictors of outcomes were prospectively analyzed. The mean operative time and mean warm ischemia time were 192.7 and 2.2 min, respectively. Mean estimated blood loss was 195.3 ml. The mean post-transplant serum creatinine levels and Modification of Diet in Renal Disease study equation for estimating glomerular filtration rate were 1.1 mg/dl and 68 ml/min/1.73 m^2, respectively at 5 years after VLDN. The intra-operative and post-operative complication rate were 3.1% and 6.3%, respectively. Delayed renal function, 5-year graft survival, and complication rates of recipients were 1.1%, 98.4%, and 0.4%, respectively. Predictors of operative time were medical history, vessel anomaly, and surgeon experience (>50 cases). The single predictor of intra-operative complications was vessel anomaly. Standardized VLDN is feasible and safe. Our data on long-term outcomes can assist in demonstrating the long-term safety of donor nephrectomy to potential donors. To compare VLDN to other types of donor nephrectomy, a prospective multicenter study must be performed.

Introduction

Living donor nephrectomy (LDN) was introduced in the 1950s and has since played an important role in the treatment of end-stage renal disease. According to the U.S. Organ Procurement and Transplantation Network and the Scientific Registry of Transplant Recipients 2008 annual report, more than 75,000 patients were included on the renal transplantation list in 2007, and only 16,000 patients (21.3%) received a transplant.Ascribable to a shortage of deceased kidneys, living donation is an important source for renal transplantation [1]. For this reason, there have been many trials to increase living donation including expanding donor criteria to include individuals previously deemed unsuitable as living donors [2]. However, it is necessary to educate potential donors on the safety of LDN technique with favorable long-term outcomes for both donors and recipients.

Laparoscopic LDN (LLDN) including hand-assisted laparoscopic LDN (HALLDN), has been used as much as open LDN (OLDN) to minimize invasiveness [3–8]. Large-scale studies have compared the outcomes [9–12] and safety of LLDN to OLDN [4,5]. Although these studies reported comparable long-term outcomes for LLDN and OLDN, OLDN is still used by surgeons not familiar with LLDN, by institutions that do not have laparoscopic equipment, and in complex cases, such as those presenting severe adhesions or vascular anomalies. To overcome the invasiveness of OLDN, mini-incision LDN (MILDN), which leaves a small incision similar to that of LLDN, has been developed. Several publications have reported the feasibility and safety of MILDN, and suggest that MILDN provides an alternative to conventional OLDN [13,14] as well as outcomes comparable to LLDN [15].

The LDN techniques must ensure donor safety and minimize complications. To achieve this goal, we have developed and attempted to standardize our retroperitoneal minilaparotomy technique as an alternative to open technique [16,17]. To date, no published large-scale MILDN study has incorporated standardization and long-term follow-up data. Therefore, we report the first data regarding the safety and long-term patients' outcomes for standardized video-assisted minilaparotomy living donor nephrectomy (VLDN) technique.

Materials and methods

Patients

From January 2003 to December 2009, 615 consecutive LDNs were performed at Yonsei Severance Hospital in Seoul, Korea by two surgeons. All procedures were performed with video-assisted minilaparotomy surgery, which was developed as a standardized retroperitoneal minilaparotomy renal surgery at our institution [16]. We prospectively reviewed data from all 615 patients. The Institutional Review Board of the Yonsei Severance Hospital approved this study. Despite being encouraged to visit the clinic annually, donors were lost to follow-up or wanted to transfer to their local hospital; therefore, the study population decreased over time (year 1: 356 patients; year 2: 214 patients; years 3–4: 42 patients; and years 5–7: 97 patients).

Donors underwent routine preoperative screening including medical history, physical examination, and blood and urine analysis including Modification of Diet in Renal Disease study equation for estimating Glomerular Filtration Rate (MDRD GFR), 24-h urine creatinine clearance, and technetium-99m-diethylene triamine pentaacetic acid (99mTc-DTPA) renal scintigraphy. Donors with a MDRD GFR <80 ml/min/1.73 m^2 and 24-h urine creatinine clearance <80 ml/min/1.73 m^2 were excluded. In a small number of exceptional cases such as donation to an elderly spouse, an estimated GFR <80 ml/min/1.73 m^2 was allowed. We accepted the estimated GFR by priority; however, we also considered creatinine clearance, especially when we had to decide to accept donation from a candidate whose estimated GFR was below 80 ml/min/1.73 m^2.

High-resolution computed tomographic angiography with 3-dimensional reconstruction was performed to evaluate kidney and vascular anatomy. In general, the left kidney was removed to secure enough length of the renal vein (RV). Surgeons collected intra-operative data according to donor protocol including operative time (OPT), estimated blood loss (EBL), warm ischemic time (WIT), intra-operative complications, vessel and ureter anomaly, and any unusual intra-operative events. Postoperative data, including complications, length of hospital stay, and follow-up data were prospectively recorded by the research fellows. Complications were scored according to the modified Clavien grading system for LDN as described by Kocak *et al.* [18]. Postoperatively, donors could stay longer if desired. Follow-up visits were scheduled 3 weeks, 3 months, 6 months, and 12 months after the operation and annually thereafter if donor was available.

Surgical technique

The VLDN was performed using a laparoscopic set and a specially designed self-retaining retractor set including a piercing abdominal wall elevator (Thompson Surgical, MI, USA), previously described (Fig. 1) [17,19,20]. The main body, traction bars, and blades of the retractor are typically used for this procedure (Thompson Surgical, MI, USA), and we modified the angle of the blades and added the piercing abdominal wall elevator set. Afterward, we adopted a telescope and flexible light wand. With the patient in the 30-degree flank position, a transverse incision (female, 6 cm; male, 7 cm) was made from the costal margin of the 10th rib and medially extended. For the retroperitoneal approach, the peritoneum was dissected from the abdominal wall. Using the piercing abdominal wall elevator, the abdominal wall was punctured inside out at sites 4 cm caudomedially and cephalomedially

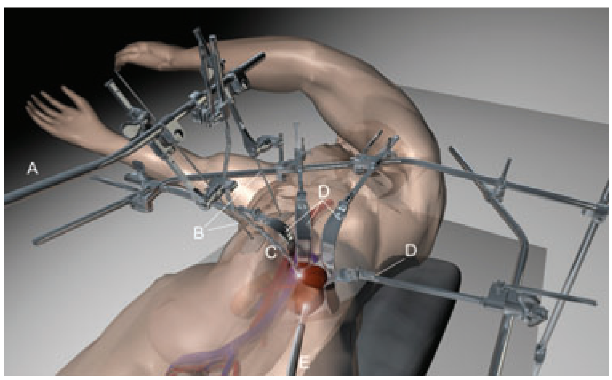

Figure 1 Setting for video-assisted minilaparotomy living donor nephrectomy. (a) Horizontal bar. (b) Piercing abdominal wall elevator. (c) Flexible light wand. (d) Horizontal self-retaining retractors. (e) Telescope.

from the medial incision margin. The piercing elevator, which was connected to the horizontal bar, allowed enough retroperitoneal space by tenting on the abdominal wall. Horizontal self-retaining retractors were used for traction. In addition to the minilaparotomy view, a magnified view was generated by placing the telescope through a 5-mm laparoscopic trocar placed 7 cm below the incision. A flexible light wand and a newly designed folded handle instrument provided surgeons with an optimal, unobstructed view. Since we adopted Unitrac® (Aesculap Surgical Instruments, Germany) in 2007, a solo surgery was possible by substituting the first assistant [21].

Ureter, kidney, and renal hilar dissections were performed as previously described [20]. During the ureter resection, another piercing retractor was used to sweep the peritoneum medially. The renal artery (RA) was double- or triple-clipped with large endoclips and in recent cases (last 3 years), secured with a non-absorbable suture. During the right RA dissection and clipping, the inferior vena cava was anteromedially lifted with a malleable self-retaining retractor. For the left RV, we applied an extra-large Hem-o-Lok clip proximal to the adrenal vein stump. This was then oversewn with 5-0 polypropylene. For the entire right RV, a Satinsky clamp was applied to the base of the RV, and then the RV was transected and sutured. The kidney was removed through the minilaparotomy incision covered with a retrieval bag. A drain was placed through a laparoscopic port after hemostasis.

Definitions and statistical analysis

Delayed graft function was defined as the need for at least one dialysis session during the first 7 days following transplantation. Graft loss was defined as return of the recipient to permanent dialysis or death. To assess the learning curve of surgeons, we compared their performance with their first 50 cases (total 100 cases) with that after their first 50 cases (surgeon experience >50, total 515 cases). Univariate analysis using the chi-square test and Student's *t*-test was performed to identify predictors of outcomes. Multivariate logistic regression and multiple linear regression analysis were also applied. All statistical analyses were performed using Predictive Analysis Software (Version 17.0, SPSS, IL, USA). $P < 0.05$ was considered statistically significant.

Results

All 615 VLDN cases were successfully performed without conversion to conventional OLDN or kidney loss. Preoperative donor characteristics are presented in Table 1. The mean (SD) operative time and mean (SD) warm ischemic time were 192.7 ± 42.8 min and 2.2 ± 1.2 min, respectively, and the mean (SD) estimated blood loss was 195.3 ± 229.8 ml. The mean (SD) wound length was 6.5 ± 0.5 cm, and the mean (SD) hospital stay was 4.3 ± 1.8 days. The mean post-transplant serum creatinine levels 1, 2, 3–4, and 5–7 years after the operation were 1.19 ± 0.24, 1.18 ± 0.24, 1.15 ± 0.23, and 1.15 ± 0.21 mg/dl, respectively. The MDRD GFRs 1, 2, 3–4, and 5–7 years after the operation were 65.0 ± 11.9, 65.5 ± 11.8, 67.5 ± 11.4, and 67.6 ± 10.1 ml/min/1.73 m^2, respectively (Fig. 2). Regarding the mean % MDRD GFR relative to the preoperative level, the 1-year and 5–7-year % MDRD GFRs were 68.5% and 73.1%, respectively.

Approximately 3.3% (20/615) of donors with MDRD GFRs of 70–80 ml/min/1.73 m^2 were used exceptionally. These 20 donors consisted of 5 men and 15 women, and their mean age was 54.1 ± 6.1 years (range, 39–66 years). Their preoperative mean MDRD GFR and 24-h urine creatinine clearance were 76.9 ± 0.9 ml/min/1.73 m^2 and 82.9 ± 10.7 ml/min/1.73 m^2, respectively. At 1 and 5 years after the operation, their mean MDRD GFRs were 57.0 ± 5.3 (range, 48.9–68.7) and 60.1 ± 5.8 (range, 50.3–67.7), respectively.

Table 1. Preoperative characteristics of 615 donors.

Variable	Mean (SD), frequency (%)
Height (cm)	Mean 165.2 (8.3)
Weight (kg)	Mean 64.2 (10.4)
BMI (kg/m^2)	Mean 23.5 (3.1)
Age (yr)	Mean 39.5 (11.0)
Male (n)	314 (51.1)
Smoking (n)	136 (22.1)
Medical history	70 (11.4)
Hypertension	11 (1.8)
Diabetes Mellitus	0
Mild anemia in female (Hemoglobin 10–11 g/dl, n)	21 (3.4)
Mild Dyslipidemia (Total cholesterol 220–270 mg/dl or Triglyceride 150–200 mg/dl, n)	38 (6.2)
Previous surgical history (n)	15 (2.5)
Right kidney (n)	114 (18.5)
Vascular anomalies (n)	237 (38.5)
Multiple renal arteries (n)	73 (11.9)
Early bifurcation of renal artery*(n)	43 (7.0)
Multiple renal veins (n)	45 (7.3)
Retroaortic renal vein (n)	5 (0.8)
Other vessel anomalies**(n)	71 (11.5)
Duplicated ureter (n)	2 (0.3)

*Dividing within 1 cm of the aorta.

**Gonadal vein anomalies, lumbar vein anomalies, aberrant vessel, double inferior vena cava, inferior vena cava interposition.

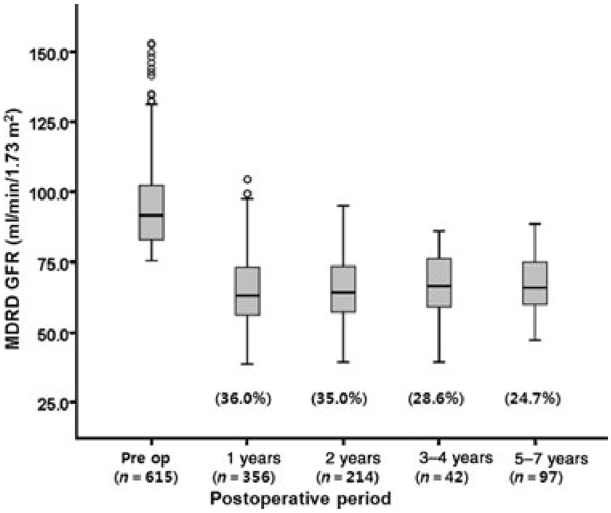

Figure 2 Serial changes of serum creatinine levels and MDRD GFR. The percentage in the graph is % with MDRD GFR <60 ml/min/ 1.73 m^2.

No end-stage renal disease (ESRD) developed in follow-up period. The mean (SD) follow-up period was 2.7 ± 1.9 years. Actual donor survival rates during follow-up period were 100%.

At 1 and 5–7 years after donation, proteinuria developed in 0.3% (1/356, one at 1 +) and 3.1% (3/97, one trace and two at 1 +) of followed donors, respectively.

At the 1-year follow-up, 1.1% (4/356) of donors had new-onset hypertension. Among them, two donors started antihypertensive therapy. Both of them maintained stable blood pressure with a single antihypertensive medication and behavioral changes until the last follow-up 19 and 23 months after donation, respectively. Others were treated with behavioral changes and without medication.

In Table 2, intra-operative and postoperative complications are compared to a large-scale meta-analysis [4], which compared OLDN and LLDN outcomes. Among intra-operative complications (n = 19, 3.1%), one case of RV laceration required a blood transfusion. However, there were no grade 2b, 2c, 3, or 4 intra-operative complications requiring additional therapeutic interventions, open conversion or leading to residual disability, renal failure or donor death. Among postoperative complications (n = 39, 6.3%), the grade 1 complication rate was 69.2%; but no grade 2c, 3, or 4 complications were reported. However, there were two significant events: an inferior vena cava laceration in one of a surgeon's initial 50 cases; and a RV stump partial tearing, which resulted in approximately 1950 ml blood loss in a vessel anomaly case. There was one case of partial RA clip slippage which we secured with an additional non-absorbable suture. Patients who presented with postoperative hemodynamic instability or hemoglobin level <8 g/dl required a 1–2-unit blood transfusion (1.5%). In two suspected cases of progressive bleeding, computed tomography was performed, but no active bleeding foci were identified and patients were stabilized following transfusion. Hematoma in the renal fossa was detected in one patient by computed tomography after the patient presented with mild fever and hemoglobin levels reduced from 14.2 to 9.6 g/dl. However, this patient recovered without a transfusion. No cases required reoperation in this study. Postoperative neuralgia or incisional hernia was not reported during the follow-up period.

Recipient characteristics and outcomes are reported in Table 3 of seven recipients showing delayed graft function. Among them, one recipient who developed intra-operative hypovolemic shock presented a primary nonfunctioning kidney and died from pneumonia aggravation within 1 month. The causes of delayed graft function were urinary tract infection (n = 1), acute rejection (n = 3), catheter obstruction referable to blood clots (n = 1), and acute tubular necrosis ascribable to drug nephrotoxicity (n = 1). These six recipients recovered within an average of 13 days after transplantation.

The univariate analysis to identify predictors is provided in Table 4. In multivariate analysis, we considered univariate results and previously reported predictors such as age, gender, and body mass index (BMI) (Table 4) [10]. Patients with a medical history had a longer OPT compared to patients without medical history by 12.7 min (95% confidence interval [CI], 1.2–24.1). Patients with vessel anomalies had a longer OPT by 9.2 min (95% CI, 0.7–17.6) and a 3.4-fold higher rate of intra-operative complications (95% CI, 1.6–6.8) compared with patients without vessel anomalies. If the surgeon had performed more than 50 procedures, mean OPT decreased by 11.4 min (95% CI, −21.6 to −1.2). No factor significantly predicted WIT, EBL or postoperative complications. While univariate analysis demonstrated that previous surgical history affected OPT, multivariate analysis did not identify this as a significant factor.

Discussion

Safety and efficacy are the most important concerns for LDN. Previous studies reported that OLDN has advantages in terms of OPT and WIT, whereas LLDN has advantages related to EBL, pain, and length of hospital stay [4,5].

In our study, mean OPT (192.7 min) was longer than previous OLDN data (mean, 140–164 min) [22,23] because of an average of 15 min required to set the piercing retractors. However, mean OPT was comparable to previous large-scale LLDN studies (mean, 180–221 min)

Table 2. Intra-operative and postoperative complications of 615 donors.

Grade*	% of all complications	% of total series		Outcome of interest	Comment	% of meta analysis (4) (study group (n): LLDN vs. OLDN)
		Total available data = 615				
Intraoperative complications		3.1%	n = 19		All vascular injuries are immediately repaired with polypropylene suture	Overall (24): 4.9 vs. 4.6% RCT only (3): 5.5% vs. 11.9% RCT+ High prospective study (12): 5.4% vs. 7.0%
1	73.7% (n = 14)	2.3%	0.3% (n = 2)	IVC suture site oozing	Right side	
			0.2% (n = 1)	Small RA branch tearing		
			0.2% (n = 1)	RA stump oozing		
			0.2% (n = 1)	Unexpected RA clipping while RV clipping		
			0.5% (n = 3)	RV branch oozing		
			0.2% (n = 1)	RV stump oozing	Left side	
			0.2% (n = 1)	LV bleeding		
			0.3% (n = 2)	LV ligation slippage		
			0.2% (n = 1)	AV bleeding		
			0.2% (n = 1)	AV clip site laceration		
2a	26.3% (n = 5)	0.8%	0.3% (n = 2)	RA branch laceration	Bleeding 750cc, 950cc	
			0.2% (n = 1)	RA clip partial slippage	Bleeding 800cc	
			0.2% (n = 1)	RV stump partial tearing	Bleeding 1950cc, transfusion	
			0.2% (n = 1)	Bleeding from LV-GV anomaly	Bleeding 1000cc	
2b,2c,3,4	0% (n = 0)		0% (n = 0)			

Table 2. continued

Grade*	% of all complications	% of total series		Outcome of interest	Comment	% of meta analysis (4) (study group (n): LLDN vs. OLDN)
		Total available data = 615				
Post-operative complications		6.3%	n = 39		All vascular injuries are immediately repaired with polypropylene suture	Overall (34): 10.9 vs. 10.8% RCT only (3): 16.7% vs. 8.6% RCT+ High prospective study (10): 13.5% vs. 13.5%
1	69.2% (n = 27)	4.4%	1.8% (n = 11)	Wound dehiscence	No need for second wound closure	Wound infection (10) (1.9% vs. 3.2%)**
						Incisional hernia (7) (1.1% vs. 3.1%)**
			0.8% (n = 5)	Wound site pain	Delayed discharge	Chronic wound pain (7) (1.1% vs. 6.4%)**
			0.7% (n = 4)	Urinary retention	Catheterization	Urological (11) (2.9% vs. 4.0%)**
			0.3% (n = 2)	Prolonged ileus	Delayed discharge day 5, 10	
			0.3% (n = 2)	Paresthesia of scrotum and thigh		
			0.5% (n = 3)	Lymphorrhea	Delayed drain removal day 5,7,8 Low fat, MCT diet, TPN	
2a	28.2% (n = 11)	1.8%	1.5% (n = 9)	Blood transfusion	Postoperative bleeding, no need for reoperation	Overall blood transfusion (16) (2.8% vs. 1.6%)** Reoperation because of bleeding (13) (1.7% vs. 0.7%)**
			0.2% (n = 1)	Hematoma in renal fossa	No intervention required	Vascular (12) (2.6% vs. 1.4%)**
			0.2% (n = 1)	Lymphorrhea	Delayed drain removal day 15 Low fat, MCT diet, TPN	
2b	2.6% (n = 1)	0.2%	0.2% (n = 1)	Lymphocele	Pig tail insertion day 29 Readmission for 1 week Low fat, MCT diet, TPN	
2c,3,4	0% (n = 0)		0% (n = 0)			

RCT, randomized controlled trial; LV, lumbar vein; AV, adrenal vein; GV, gonadal vein.
*According to the modified Clavien grading system described by Kocak *et al.* (18).
**Numbers and percents are from overall study groups.

Table 3. Recipient characteristics and outcomes.

Variable	Mean (SD), frequency (%)	Meta analysis (4) (LLDN vs. OLDN)
Age (years)	Mean 41.3 (11.0)	
Male (%)	Mean 388 (63)	
MDRD GFR at 1 year (mg/dl)	Mean 53.1 (25.2)	
Delayed graft function (n)	7 (1.1)	Delayed graft function (5.4% vs. 3.9%) (RCT: 9.8% vs. 7.1%) (RCT+ High prospective: 6.2% vs. 6.2%)
Acute rejection (n)	95 (15.4)	
Total graft loss at total 7 years (n)	20 (3.3)	
Patient death with functioning graft kidney	8 (40)*	
Acute rejection	6 (30)*	
Glomerulonephritis	2 (10)*	
Non-compliance for medication	2 (10)*	
Primary non-function	1 (5)*	
Infection	1 (5)*	
Graft survival at 1 year (n)	608 (98.9)	1-year graft loss (4.2% vs. 4.8%) (RCT+ High prospective: 6.3% vs. 4.0%)
Graft survival at 5 years (n)	605 (98.4)	
Recipient survival at 5 years (n)	610 (99.2)	
Ureteral stricture (n)	2 (0.3)	Ureteral complication (5.1% vs. 5.6%)
Vesicoureteral reflux (n)	4 (0.7)	(RCT: 1.6% vs. 2.4%)
Vesicoureteral anastomosis site leaking (n)	2 (0.3)	(RCT+ High prospective: 3.2% vs. 2.8%)
Vascular complication (n)	1 (0.2)	

RCT, randomized controlled trial.
*Percents for total graft loss (n = 20).

[10,11,22,23]. Mean WIT (2.2 min) for VLDN was similar to that reported for OLDN (mean, 1.4–3 min) and shorter than that reported for LLDN (mean, 2.8–6 min)[10,22,23]. Mean hospital stay (4.3 days) tended to be longer than that reported for OLDN and LLDN [4]. Generally, we recommended discharge on postoperative day 2 depending on the donor's postoperative condition; however, the relationship between donors and recipients led donors to stay longer alongside the recipient. The small expenditure for a ward stay ($11 daily) in Korea often results in longer hospital stays.

As for the renal function, 1 year follow up serum creatinine levels (1.2 mg/dl; 105.3 μmol/l) and 5–7 year follow up serum creatinine levels (1.1 mg/dl; 100.8 μmol/l) were similar to those of previously reported studies (107–110 μmol/l at postoperative 1 year, 80–97 μmol/l at 5 years and 1.1 mg/dl at 15–34 years) [15,24,25]. Mjoen *et al.* reported 56.1 ml/min/1.7 m^2 for postoperative 1 year MDRD GFR and 61.0 ml/min/1.7 m^2 for postoperative 5 years MDRD GFR. The findings of this study also showed a similar tendency with these results (65 and 68 ml/min/1.7 m^2 for postoperative 1 year and 5 years, respectively). On a large scale (total 3698 enrolled donors) long-term follow-up data, MDRD GFR was 64 ml/min/1.7 m^2 after a mean 12.2 years, and it was maintained within similar levels (63–65 ml/min/1.7 m^2) after 20 years. In the same data set, end stage renal disease was developed in 11 donors, at the rate of 180 cases per million persons per year. This rate was compared with a rate of 263 per million per year in the general population [26]. In our study, 31.5 and 26.9% of GFRs were lost after 1 and 5–7 years, respectively. In previously reported data, the 3-month follow up % MDRD GFR was 64–68% of the pre-donation level [27]. Another study reported that % MDRD GFRs at the 1- and 3-year follow-ups were 61.0 and 62.1%, respectively [28].

In the presented study, ESRD was not developed in the study population. However, there were three ESRD patients among the 2200 donors who underwent LDN between 1979 and 2002. The main cause of ESRD was intemperate life with alcohol and smoking; however, there were no correlations with their family medical history. During the follow-up period before ESRD was developed (mean 8.3 years), two of the patients refused to participate in follow-up procedures, and they ignored their health care. Just as was emphasized in the Amsterdam

Table 4. Univariate and multivariate predictors of donor outcomes.

Univariate predictors

Outcome	Significant factors	*P* value
Operative time	Medical history	0.007
	Vessel anomaly	0.045
	Surgeon experience >50	0.013
	Previous surgical history	0.036
Warm ischemic time	None	
Estimated blood loss	None	
Intra-operative complications	Vessel anomaly	<0.001
Postoperative complications	Surgeon experience >50	0.049

Multivariate predictors

Outcome	Significant factors	Mean effect or odds ratio	95% Confidence interval	*P* value
Operative time	Medical history	12.7 min	1.2–24.1 min	0.016
	Vessel anomaly	9.2 min	0.7–17.6 min	0.045
	Surgeon experience >50	−11.4 min	−21.6 to −1.2 min	0.038
Warm ischemic time	None			
Estimated blood loss	None			
Intra-operative complications	Vessel anomaly	3.4	1.6–6.8	<0.001
Postoperative complications	None			

forum guidelines for living donor candidates [29], lifestyle control after donor nephrectomy is also important to maintain the renal function.

On meta-analysis, both intra-operative and postoperative complication rates (3.1% and 6.3% ,respectively) were lower than those of OLDN (4.9% and 10.9%) and LLDN (4.6% and 10.8%) (Table 2)[5]. Referable to different definitions and classifications, reported complication rates vary (range, 0–26.1%)[7,9–12,22,23,30]. When comparing our data to other large-scale studies[7,9,12], the overall complication rate (9.4%) was favorable (OLDN, 14.9–15.7%; LLDN, 8.2–23.9%). Most complications were also low-grade. A few previous studies reported details of intra-operative complications for LDN [9,12]. However, vascular injury during LDN could be fatal to donors and recipients, so we focused on avoiding vascular injury and specifically reported on vascular accidents. The retroperitoneal approach enabled us to avoid the bowel complications repeatedly reported for OLDN and LLDN [7,9,12,31]. Grade 1 wound dehiscence was the most common postoperative complication. Overall transfusion rate (1.75%) was similar to those reported for MILDN (1.9%) [15], OLDN (1.6%), and LLDN (2.8%) [5]. In this study, intra-operative transfusion was performed for only one case (0.16%, 1/615) ascribable to RV injury. This rate is lower than that reported by a large heterogeneous LDN study (0.29%, 4/1022) [9]. The dual vision and standardization enabled VLDN to be a powerful technique for controlling vascular accidents. It could provide magnified view of the renal hilar structures, provide an adequate range of vision and give additional view from the critical angle needed to perform this procedure. Surgeons could choose either direct or endoscopic according to their convenience.

As for the quality of life following VLDN, we evaluated pain and satisfaction using scales from 1 to 10, and also evaluated quality of life, with the 36-item Short Form questionnaire in our previously published study. In this study, we found that VLDN has better outcomes with regard to pain, recovery time, and cosmesis than OLDN [20]. VLDN is also more cost effective than LLDN (average cost for operation, instrumentation, and anesthesia in 2010: OLDN, $333; VLDN, $549; and LLDN, $826). Because most of the instruments of this self-retaining retractor set could be replaced by other retractors already in use in the operating room, the cost of equipment was not excessive.

To make it easy to compare our results to those of other studies, we used the modified Clavien grading system. This system is convenient because: 1) the original Clavien grading system is familiar to surgeons; and 2) other grading systems for LDN, such as that described by Tan *et al.* [32], and is specified in terms of intra-operative and postoperative complications, are not frequently cited and are difficult to identify. However, in the modified Clavien grading system, certain limitations must be overcome, such as separating intra-operative and postoperative complications.

Recipient outcomes, including delayed renal function, 1-year graft loss, and complication rates (1.1%, 1.9%, and 1.5%, respectively), were lower in our VLDN series compared with the meta-analysis for OLDN and LLDN (Table 3) and a large dataset consisting of 5532 recipients [33]. The 5-year graft survival rate (98.4%) for VLDN was also higher than those for OLDN (80%) and LLDN (79%) [33]. Standardizing the procedure minimized kidney manipulation without increasing perirenal pressure, resulting in a gasless surgery. Thus, we could maintain renal flow well during VLDN, in contrast to LLDN. Therefore, recipient outcomes could be improved by reducing potential ischemia time during VLDN [17]. Ureteral and vascular complications (1.3%, 0.2%) were also minimal (Table 3).

Medical history, vessel anomaly, and surgeon experience (>50 cases) were significant predictors of OPT in VLDN. In a previous study including 512 LLDN patients [10], the following factors predicted OPT: operating surgeon, donor age >50 years, female gender, hand-assistance, and right-sided nephrectomy. These differences could originate from differences in the surgical method. However, the observation that right-side VLDN does not require a longer OPT is significant. Our data indicate that operation times were longer in patients with a medical history; however, we could not explain these unexpected results. We thought that this is some kind of coincidental situation or we carefully assume that the miss of the waiting time for recipient preparation or co-operation on operation record could affect this result. Further evaluation will be needed to determine the effects of specific medical conditions on donor outcome. In relation to WIT, postoperative complications, and EBL; no factors, including previously reported prognostic factors [10], were predictors or risk factors in VLDN. The most powerful predictor of VLDN outcomes was vessel anomaly, which significantly predicted intra-operative complications and OPT. A major advantage of VLDN is effective standardized retraction; therefore, surgeon experience and right-side surgery are not expected to affect WIT.

Currently, LLDN, including HALLDN, is widely used and considered superior to OLDN [34,35]. However, OLDN is still needed and our data show that VLDN offers an alternative procedure to OLDN.

To enhance the safety of LDN, we had standardized each procedural step of VLDN. We standardized VLDN as follows: First, we published a VLDN textbook and educational video that included all steps of the procedure and helpful tips on intra-operative accidents [36]. These materials helped the surgeons perform this technique safely and efficiently. Second, we introduced a piercing abdominal wall elevator and used horizontal self-retaining retractors and the Unitrac® to create enough retroperitoneal space and stabilize the sustained retraction. Third, the hilar procedures were more easily done with video-assisted visualization of the surgical field. Lastly, a freely bent, malleable, self-retaining retractor was used for traction of delicate vessels, especially the inferior vena cava during right VLDN and in cases with multiple vessels [37]. Hooking angle, tension, and the direction of retracting force were well controlled and sustained by adequate use of malleable retractors (Fig. 1). The standardization trial of VLDN allowed us to avoid intra-operative complications, and also to control the adverse event immediately and safely when it occurred.

This study has some limitations. We considered the estimated GFR using the MDRD study equation as a priority to accept donations. However, this formula has not been validated in living kidney donors and accurate determinations of renal function require measured GFR. Concerning the assessment of the VLDN technique, there was no comparison of VLDN and LLDN data from our institution, because we did not perform LLDN. In addition, we could not compare our VLDN and OLDN series as a result of the time that had elapsed between these studies. The current unreported LLDN complication rate in centers of excellence, frequently less than a few percent, could not be considered. Therefore, a prospective multicenter comparison of different LDN techniques is needed.

Currently, LLDN is considered superior to OLDN in the United States and is no longer considered controversial when done by experienced laparoscopic surgeons. However, for those who cannot perform LLDN for previously mentioned reasons, the technique of MILDN such as VLDN may be helpful. Also large-scale long-term outcomes of such technique are needed.

In conclusion, VLDN is a feasible and safe technique, providing a safe and convenient alternative to OLDN with favorable outcomes and a standardized procedure. Our data on long-term outcomes can be used by physicians to provide specific data on the practical risk and favorable outcomes to potential donors. Ultimately, this will help to increase living kidney donations. A prospective, multicenter study should be done to directly compare this technique to other types of LDN.

Authorship

KHC: participated in research design, the writing of the paper, the performance of the research and data analysis, and contributed new analytic tools. SCY: participated in research design, critical revision of the manuscript for scientific and factual content and supervision. SRL, HGJ and DSK, DJJ, MSK, YSK, SIK: participated in the performance of the research and data analysis. KHR: participated in the performance of the research and data analysis, critical revision of the manuscript for scientific and factual content and supervision. WKH: participated in research design, the performance of the research and data analysis, and contributed new analytic tools and supervision.

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