

Transition From Hand-Assisted to Pure Laparoscopic Donor Nephrectomy

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ABSTRACT

Background and Objectives: We compared perioperative donor outcomes and early graft function of hand-assisted laparoscopic donor nephrectomy (HALDN) and pure laparoscopic donor nephrectomy (PLDN) performed by a single surgeon, to define the feasibility of technical transition from HALDN to PLDN.

Methods: From October 1, 2012, through June 30, 2014, 60 donor nephrectomies were performed by a single surgeon who lacked experience with laparoscopic renal surgery: the first 30 by HALDN and the last 30 by PLDN. Operative and convalescence parameters were compared, as were intra- and postoperative complications within 90 days according to the Satava and Clavien-Dindo classifications, respectively. Binary logistic regression analysis was used to estimate the association of baseline characteristics with complications.

Results: Baseline characteristics were similar in the 2 groups, except for American Society of Anesthesiologists score II (10.0% vs 43.3%; $P = .007$). All procedures were completed as planned. All operative and convalescence parameters of donors and graft outcomes were similar in the 2 groups, as were overall rates of intraoperative (43.3% vs 36.7%, $P = .598$) and postoperative (86.7% vs 70.0%; $P = .209$) complications. No factor was significantly predictive of intraoperative complications, whereas sex (female vs male, odds ratio, 0.183; $P = .029$) and learning curve (odds ratio, 0.602; $P = .036$) were significant determinants of postoperative complication.

Conclusion: The technical transition from HALDN to PLDN does not involve a steep learning curve for sur-

geons less experienced with laparoscopic renal surgery and maintains similar perioperative donor and graft outcomes.

Key Words: Hand-assisted, Intraoperative complications, Laparoscopic, Living donors, Postoperative complications.

INTRODUCTION

The first kidney allotransplantation in the world between living patients was performed in 1952 in Paris, although the kidney failed 3 weeks later.¹ Since its inception, living-donor kidney transplantation has shown superiority over deceased-donor transplantation, with shorter cold ischemia time, the use of perfect kidneys from perfectly healthy donors, and reduced waiting time for the recipient.² These advantages have increased the use of living-donor kidneys.³ Because people volunteering for a surgery that will not provide any personal physical health benefits are in particular need of a safe operation, the benefits for recipient and society must be balanced against the potential harm to the donor.⁴ Thus, surgeons performing living-donor kidney transplantation have focused on the quality of life and safety of the donor, as well as on graft function, leading to the development of minimally invasive donor nephrectomy techniques.

The first pure laparoscopic donor nephrectomy (PLDN) was reported by Ratner et al.⁵ in 1995. Several subsequent studies found that laparoscopic donor nephrectomy (LDN), whether hand-assisted or not, was superior to open donor nephrectomy in terms of the donor's recovery, with less pain, reduced estimated blood loss, and shorter hospital stay.^{2,6,7} Although LDN has several disadvantages when compared to open donor nephrectomy, including longer operative and warm ischemia times, it does not increase intraoperative and postoperative donor complications or compromise graft function.^{6,8} However, the technical difficulties associated with PLDN have prevented its more rapid adoption. The subsequent development of hand-assisted laparoscopy for harvesting the donor kidney has resulted in a wider acceptance of minimally invasive surgery.⁹

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The Organ Procurement and Transplantation Network/Scientific Registry of Transplant Recipients estimated that, in 2012, 95% of kidneys were harvested from donors by laparoscopic nephrectomy, whether hand-assisted or not.³ Although about 60% of living donor nephrectomies have been performed by hand-assisted procedures, the proportion harvested without hand assistance is continuously increasing.³ Fewer studies, however, have compared these 2 laparoscopic techniques, and these studies have demonstrated conflicting results. In the present study, we sought to determine the feasibility of technical transition from HALDN to PLDN by comparing perioperative donor outcomes and early graft function of hand-assisted laparoscopic donor nephrectomy (HALDN) and PLDN performed by a single surgeon.

MATERIALS AND METHODS

Baseline Characteristics

The study protocol was approved by the institutional review board of the Asan Medical Center (No. 2014-0852). A prospectively collected database of 60 donor nephrectomies performed by a single surgeon (DY) from October 1, 2012, through June 30, 2014, was reviewed. The surgeon had less than 2 y of actual experience after completion of a 2-y urology fellowship. The first 30 donor nephrectomies were performed by HALDN and the last 30 by PLDN. Before surgery, the renal vascular anatomy and relative renal function of both kidneys were examined by computed tomography angiography and diethylene triamine penta-acetic acid scintigraphy. The kidney to be extracted was determined on the basis of relative renal function and number of arteries. If the difference in relative renal function was $\leq 5\%$, and both kidneys had a single artery, the left kidney was preferred. Baseline data included patient age, sex, relationship to recipient, body mass index, medical and surgical histories, American Society of Anesthesiologists (ASA) score, laterality, number of arteries and veins, hemoglobin concentration, and glomerular filtration rate (GFR). GFR was estimated from serum creatinine concentration with a variation of the Modification of Diet in Renal Disease equation.¹⁰

Surgical Techniques

HALDN was performed as previously described, with minor modifications.^{9,11} Donor patients undergoing right-sided HALDN were placed in a 45° oblique position with the left side down while under general anesthesia. A 9-cm incision was made below the level of the umbilicus along

the lateral border of the right rectus muscle for insertion of the GelPort laparoscopic system (Applied Medical, Rancho Santa Margarita, California). A 12-mm trocar was placed above the umbilicus, a second 12-mm trocar was placed below the costal margin in the right midclavicular line, and a 5-mm trocar was placed approximately 2 cm from the tip of the right 12th rib for retraction. While under general anesthesia, donors undergoing left-sided HALDN were placed in a 45° oblique position with the right side down. A 9-cm incision was made between the level of the xiphoid process and the umbilicus for insertion of the GelPort laparoscopic system (Applied Medical). A 12-mm trocar was placed below the level of the umbilicus in the left midclavicular line, a second 12-mm trocar was placed more caudally in the left anterior axillary line, and a 5-mm trocar was placed approximately 2 cm from the tip of the left 12th rib for retraction.

PLDN was performed as previously described, with minor modifications, using the umbilical incision as the kidney extraction site.¹² For right (left)-sided PLDN, patients were placed in a 45° oblique position with the left (right) side down, while under general anesthesia. A 6-cm omega-shaped incision was made around the umbilicus for insertion of the LapDisc (Hakko Medical, Tokyo, Japan) or Dextrus (Ethicon Endo-Surgery, Inc., Cincinnati, Ohio). A 12-mm trocar was placed in the center of the hand port and used to establish pneumoperitoneum and for camera placement. A second 12-mm trocar was placed below the right (left) costal margin in the right (left) midclavicular line and a third 12-mm trocar was placed below the level of the umbilicus in the right (left) anterior axillary line. Finally, a 5-mm trocar was placed approximately 2 cm from the tip of the right (left) 12th rib for retraction.

After the white line of Toldt was incised and the colon reflected medially, Gerota's fascia was entered near the renal hilum. The renal artery and vein were completely freed of lymphatic and other perivascular tissue, avoiding any injuries to the vessels. The gonadal, lumbar, and adrenal branches were tied and divided from the renal vein. The ureter was dissected caudally to the level of the internal iliac vessels, leaving sufficient margins to ensure an adequate blood supply around it. Forty milligrams mannitol and 5000 IU heparin were administered intravenously. An extra-large Hem-o-Lok clip (Teleflex Medical, Research Triangle Park, North Carolina) was applied at the caudal end of the dissected ureter, and the ureter was divided cephalad to the clip without electrocautery. The renal artery was clamped with 1 (for left-sided) or 2 (for right-sided) extra-large Hem-o-Lok clips (Teleflex Medical) and 2 titanium clips (AutoSuture Endo Clip I; Covi-

dien Surgical, Norwalk, Connecticut). An Endopath ETS-Flex articulating endoscopic linear stapler (Ethicon Endo-Surgery, Inc.) was applied to transect the renal vein. The kidney was removed through the hand port (for HALDN) or umbilical incision (for PLDN) in an Endocatch bag (Covidien Surgical), placed immediately in sterile ice slush, and delivered to the recipient team for grafting. Fifty milligrams protamine sulfate was administered intravenously. After the abdomen was carefully inspected at a reduced intraperitoneal pressure, bleeding was controlled, and a Jackson-Pratt drain was inserted. After the hand port and trocars were removed and the pneumoperitoneum was evacuated, the wounds were closed in the usual method.

Outcome Measurements

Operative time was defined as the time between skin incision for placement of the first trocar and skin closure of the trocar wounds. Warm ischemia time was defined as the time from renal artery occlusion to immersion of the kidney in ice slush. Blood loss was estimated by the hemoglobin dilution method.¹³ Postoperative pain was assessed with a patient-reported visual analogue scale (VAS). Delayed graft function was defined as the need for renal replacement therapy within the first week after surgery. Nondialyzed patients were divided into those with slow and excellent graft function, based on whether serum creatinine concentration on postoperative day 7 was higher or lower than 2.5 mg/dL, respectively.¹⁴

Intraoperative complications were analyzed according to the Satava classification.¹⁵ All complications within 90 days of surgery were graded according to the Clavien-Dindo classification.¹⁶

Statistical Analysis

Continuous variables were analyzed with Student's *t* test, and categorical variables were analyzed with Pearson's χ^2 test or Fisher's exact test. Quantitative data are expressed as the mean \pm SD. Binary logistic regression analysis was used to estimate the association of baseline characteristics with intra- or postoperative complications. Correlations between outcomes and assessed variables are expressed as the odds ratio (OR) with a 95% confidence interval (CI). All statistical tests were 2-tailed, with significance set at $P < .05$. All statistical analyses were performed with SPSS Statistics, ver. 21 (IBM Corporation, Armonk, New York).

RESULTS

Table 1 shows the baseline characteristics of the 60 donors. There were no significant differences between the HALDN and PLDN groups, except that ASA score II was significantly more frequently assigned in the latter group (10.0% vs 43.3%, $P = .007$). Operative and convalescence parameters of donors and graft outcomes are outlined in **Table 2**. All procedures were completed as planned. There were no significant between-group differences in

Table 1.
Baseline Characteristics of Donors

Characteristics	HALDN	PLDN	<i>P</i>
Mean age \pm SD, y	40.6 \pm 11.2	44.3 \pm 10.8	.199
Sex, male/female	17/13	13/17	.302
Relationship to recipient, %			.137
Related	18 (60.0)	13 (43.3)	
Spouse/partner	11 (36.7)	10 (33.3)	
Distantly related	0 (0)	2 (6.7)	
Unrelated	1 (3.3)	5 (16.7)	
Mean body mass index \pm SD, kg/m	24.5 \pm 3.0	23.2 \pm 3.3	.121
Diabetes mellitus, %	0 (0)	0 (0)	–
Hypertension, %	1 (3.3)	2 (6.7)	1.000
History of abdominal surgery, %	6 (20.0)	10 (33.3)	.243
Concomitant surgery, %	1 (3.3)	1 (3.3)	1.000
ASA score, %			.007
I	27 (90.0)	17 (56.7)	
II	3 (10.0)	13 (43.3)	
Laterality, right/left, <i>n</i>	14/16	9/21	.184
Arteries, <i>n</i> (%)			.545
1	18 (60.0)	23 (76.7)	
2	11 (36.7)	5 (16.7)	
3	1 (3.3)	1 (3.3)	
4	0 (0)	1 (3.3)	
Veins, <i>n</i> (%)			.188
1	22 (73.3)	27 (90.0)	
2	7 (23.3)	2 (6.7)	
3	1 (3.3)	1 (3.3)	
Mean preoperative hemoglobin \pm SD, g/dL	14.5 \pm 1.7	14.0 \pm 1.5	.252
Mean preoperative GFR \pm SD, mg/dL	106.0 \pm 19.7	104.6 \pm 10.9	.735

Table 2.
Operative and Convalescence Parameters of Donors and Graft Outcomes

Parameter	HALDN	PLDN	<i>P</i>
Operative and convalescence parameters of donors (mean ± SD)			
Total operation time, min	208.9 ± 46.2	210.2 ± 39.7	.912
Warm ischemia time, min	6.4 ± 3.0	6.6 ± 3.9	.833
Estimated blood loss, mL	363.4 ± 243.5	453.2 ± 253.7	.167
VAS pain score on postoperative day 1	3.9 ± 1.4	4.1 ± 1.0	.526
VAS pain score at discharge	0.5 ± 0.7	0.5 ± 0.7	.856
Interval to drain removal, days	5.1 ± 2.1	4.5 ± 1.2	.179
Interval to return to regular diet, d	3.6 ± 0.9	3.3 ± 0.8	.122
Hospital stay, d	6.6 ± 1.4	6.4 ± 2.1	.667
Postoperative hemoglobin, g/dL	11.7 ± 1.6	11.8 ± 1.6	.799
Postoperative GFR, mg/dL	58.1 ± 9.5	59.6 ± 7.5	.490
Outcome, graft function, %			1.000
Excellent	29 (96.7)	30 (100.0)	
Slow	1 (3.3)	0 (0)	
Delayed	0 (0)	0 (0)	

total operation time, warm ischemia time, estimated blood loss, VAS pain scores on postoperative day 1 and at discharge, interval to removal of the drain, interval to return to a regular diet, and overall hospital stay. Only one patient in the HALDN group showed slow graft function.

Intra- and postoperative complications are outlined in **Table 3**. The rates of overall intraoperative complications were similar in the 2 groups (*P* = .598). Thirteen patients (43.3%) in the HALDN group experienced a total of 17 intraoperative errors, and 11 (36.7%) in the PLDN group experienced a total of 14 intraoperative errors. The most common intraoperative complication was adrenal gland injury (two intra-adrenal hematomas and 10 adrenal gland injuries, including 7 that required repair). The overall postoperative complication rate was similar in the 2 groups (*P* = .209). Twenty-six patients (86.7%) in the HALDN group experienced a total of 47 postoperative

Table 3.
Intra- and Postoperative Complications

Complication	HALDN	PLDN	<i>P</i>
Intraoperative complications, <i>n</i> (%)	13 (43.3)	11 (36.7)	.598
Grade I, <i>n</i>			
Venous or branch vein injury	0	4	
Adrenal gland injury	0	3	
Intra-adrenal hematoma	2	0	
Subcapsular hematoma of liver	2	0	
Liver parenchymal injury	2	0	
Spleen parenchymal injury	2	0	
Diaphragm injury	1	0	
Duodenal injury	0	1	
Visceral peritoneum laceration	0	1	
Grade II, <i>n</i>			
Adrenal gland injury needing repair	4	3	
Dislocation of clip from vessels requiring resuturing	3	1	
Arterial injury needing repair	0	1	
Dislocation of tie from vessels requiring resuturing	1	0	
Postoperative complications, <i>n</i> (%)	26 (86.7)	21 (70.0)	.209
Grade I			
Ileus needing enema or delay of diet	18	7	
Aspartate aminotransferase/alanine aminotransferase elevation	15	6	
Atelectasis	5	0	
Prolonged nausea/vomiting	2	3	
Urinary retention	3	3	
Orchalgia	2	1	
Urticaria or contact dermatitis	0	3	
Epigastric discomfort	1	2	
Atypical chest pain (negative cardiac workup)	0	1	
Wound infection	1	0	
Grade II, <i>n</i>			
Chylous ascites	1	0	
Transfusion	0	1	
Grade IIIa, <i>n</i>			
Wound dehiscence needing revision	0	1	

complications, and 21 (70.0%) in the PLDN group experienced a total of 28 postoperative complications. Ileus and aspartate aminotransferase/alanine aminotransferase elevation were commonly reported in the HALDN group. Three patients experienced major postoperative complications, defined as grade II or higher. One patient in the HALDN group had prolonged chyle leakage from a Jackson-Pratt drain; this patient was treated with long-term drainage (14 days) and a low-fat diet. One patient in the PLDN group underwent wound revision under local anesthesia for wound dehiscence. A second patient in the PLDN group had a blood transfusion for postoperative bleeding. However, this bleeding originated mainly from a concomitantly performed ovarian cystectomy site and menstruation.

None of the baseline characteristics assessed was significantly associated with intraoperative complications. Univariate and multivariate analyses of the associations between baseline characteristics and postoperative comp-

lications showed that sex (OR: 0.183, 95% CI: 0.040–0.840, $P = .029$) and learning curve (OR: 0.602, 95% CI: 0.375–0.966, $P = .036$) were significant determinants (**Table 4**).

DISCUSSION

Kidney transplantation is the treatment of choice for most patients with end-stage renal disease because of cost effectiveness, better quality of life, and longer survival compared with dialysis.^{17–19} The gap between the demand for kidney transplants and the supply of donor kidneys is continuously increasing. This discrepancy and the inadequate supply of deceased donor kidneys have resulted in greater demand for living-donor kidney transplantation.³ The increased use of living donors has made attention to donor well-being a priority, leading to the widespread adoption of minimally invasive donor nephrectomy techniques.³

Table 4.

Multivariate Logistic Regression Analysis of Baseline Characteristics Associated with Intra- and Postoperative Complications

Characteristics	Intraoperative Complication		Postoperative Complication	
	OR (95% CI)	<i>P</i>	OR (95% CI)	<i>P</i>
Type of surgery, HALDN vs PLDN	1.321 (0.469–3.721)	.598	2.786 (0.751–10.331)	.126
Age (continuous)	1.012 (0.956–1.071)	.686	0.955 (0.886–1.029)	.223
Sex, female vs male	0.836 (0.237–2.956)	.781	0.183 (0.040–0.840)	.029
Body mass index (continuous)	1.057 (0.874–1.279)	.565	0.865 (0.690–1.083)	.206
History of abdominal surgery, yes vs no	1.856 (0.532–6.477)	.332	1.463 (0.266–8.066)	.662
ASA score, II vs I	2.486 (0.773–7.993)	.127	1.577 (0.257–9.673)	.622
Side, left vs right	0.670 (0.209–2.145)	.500	2.449 (0.411–14.571)	.325
Arteries, $n \geq 2$ vs 1	2.432 (0.770–7.686)	.130	0.878 (0.160–4.834)	.881
Veins, $n \geq 2$ vs 1	1.125 (0.176–7.185)	.901	2.666 (0.234–30.411)	.430
Learning curve (classifying all consecutive cases in groups of 10)	0.830 (0.573–1.204)	.326	0.602 (0.375–0.966)	.036

Despite the increased use of LDN, few studies have compared PLDN with HALDN directly, and those studies have yielded conflicting results. Moreover, most of those studies have evaluated a small number of patients (22–100), have had a selection bias (ie, a tendency to procure more left kidneys), and were retrospective in design.^{7,20,21} Moreover, most studies have reported the outcomes of experienced laparoscopic surgeons. This study, therefore, compared perioperative donor outcomes and early graft function after HALDN and PLDN performed by a single surgeon lacking experience with laparoscopic renal surgery.

The 2 types of surgery performed by this surgeon yielded similar operative and convalescence outcomes. Most meta-analyses comparing PLDN with HALDN have reported shorter operative and warm ischemia times with HALDN than with PLDN,^{7,20,21} and lower estimated blood loss with HALDN than with PLDN.^{20,21} Although we also observed that estimated blood loss was slightly greater in the PLDN group, the difference was not statistically significant. The differences between the previous studies and this report may be because of the sequence in which the procedures were learned by our surgeon, who attempted PLDN only after surmounting the learning curve for HALDN. A recent meta-analysis reported that overall hospital stay is shorter with PLDN than with HALDN.⁷ We found that drain removal and return to a regular diet tended to take place earlier in the PLDN group, but early recovery did not bring about a reduction in overall hospital stay. This apparent contradiction may have been related to the lack of between-group differences in pain on postoperative day 1 and at discharge. Moreover, many of these patients had been transferred from other areas and may have required longer hospitalization because of difficulties in returning for early follow-up.

Both types of surgery showed excellent short-term graft outcomes. The warm ischemia times reported were somewhat longer than previously reported, both in the HALDN (our study, 6.4; prior reports, 1.6–4.4 minutes) and PLDN (our study, 6.6; prior reports 2.6–5.4 minutes) groups.^{7,20} However, the ranges of warm ischemia times observed in our patients (1.3–15.3 minutes) did not adversely affect graft outcomes in LND.^{22,23} One patient with slow graft function in our study had a short warm ischemia time (2.9 minutes), but showed good late graft function after 15 months (serum creatinine, 0.89 mg/dL). Therefore, efforts to decrease warm ischemia time, by more rapid ligation and division of the renal vessels and kidney extraction, are not warranted at the expense of potential traumatic injury to the donor or the graft.^{22,23}

The most important findings of our study included a lack of significant difference in overall intraoperative complications between the 2 groups, a finding consistent with previous reports.^{20–22} The intraoperative complication rate in our series was higher than previously reported, both in patients undergoing HALDN (our study, 43.3%; prior reports, 4%–28%) and PLDN (our study, 36.7%; prior reports, 2.8%–25%).²¹ The postoperative complication rate was also higher than reported previously, both for HALDN (our study, 86.7%; prior reports, 0%–15%) and PLDN (our study, 70.0%; prior reports, 0%–43%).²¹ The higher complication rates may be due to prospective recording by systematic classification methods, including minor complications that may have been underreported in previous studies. Most intra- and postoperative complications were grade I, and such complications could reflect the degree of completion of surgical skill or quality of postoperative management.

After adjustment for confounding factors, we confirmed that the type of surgery did not affect intra- or postoperative complications. Women were at 82% lower risk of postoperative complications than were men, which may be caused by the higher rate of genitourinary complications in men, including urinary retention and orchalgia. In addition, assessments of learning curves showed that the risk of postoperative complication was reduced by 40% for every 10 patients. This finding may be due to more frequent ileus in the initial patients, resulting from the need for bowel manipulation by hand and a relatively longer operation time. In addition, aspartate aminotransferase/alanine aminotransferase may have been elevated more frequently in the initial donors. Right kidneys tended to be procured earlier, and these patients may have needed a longer liver-retraction time, with possible risk of liver injury.

The main limitation of this study was its retrospective non-randomized design, which caused bias. The most serious bias was that our surgeon began performing PLDN after surmounting the learning curve for HALDN. Therefore, the learning curve was included as a confounding factor in logistic regression analysis of the association of baseline characteristics with patient complications. Other limitations include the small sample size. Our study may be underpowered to detect any potential differences between the 2 types of surgery. One drawback was the use of a Hem-o-Lok clip (Teleflex Medical) on the renal artery, despite the U.S. Food and Drug Administration (FDA) warning in 2006. In 2008, however, a survey of U.S. transplant surgeons showed that 28% of them still preferred Hem-o-Lok clips for LDN.²⁴ Furthermore, a review of the FDA Manufacturer and User Facility Device Experience database revealed a higher rate of

device failure associated with staplers than with Hem-o-Lok clips (3.0% vs 1.7%).²⁵

CONCLUSION

In conclusion, the technical transition from HALDN to PLDN does not have a steep learning curve for surgeons who lack experience with laparoscopic renal surgery, maintaining similar perioperative donor and graft outcomes. The occurrence of postoperative complications may be associated with the donor's sex and surgical experience. These findings should encourage less experienced transplant surgeons to start performing minimally invasive LDN.

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