Original Article

Advances in the surgical outcomes of 300 cases of pure laparoscopic living donor right hemihepatectomy divided into three periods of 100 cases: a single-centre case series

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Background: Minimally invasive surgery has been widely used for hepatobiliary operations. This study aimed to determine the safety and feasibility of pure laparoscopic living donor right hepatectomy.

Methods: From November 2015 to April 2019, 300 cases of adult pure laparoscopic living donor right hepatectomy performed at Seoul National University Hospital were divided into three subgroups of periods 1–3 of 100 cases each: 1–100, 101–200, and 201–300, respectively. We retrospectively reviewed and analysed the safety and feasibility outcomes.

Results: The operative time (period 1: 318.9±62.2 min, period 2: 256.7±71.4 min, period 3: 227.7±57.4 min) and blood loss (period 1: 419.7±196.5 mL, period 2: 198.9±197.2 mL, period 3: 166.0±130.0 mL) gradually decreased (P<0.01). Similarly, the length of hospital stay decreased (period 1: 8.1±2.0 days, period 2: 7.3±3.1 days, period 3: 6.9±2.4 days, P<0.01). There was no requirement for intraoperative transfusions or care in the intensive care unit. The overall complication rate was 20/300 (6.7%), of which 8/300 (2.7%) were Clavien-Dindo grade III and above. Complications were not different among the three periods. In terms of anatomical variations, the incidences of multiple portal veins, multiple hepatic arteries, and multiple bile ducts were 32/300 (10.7%), 11/300 (3.7%), and 161/300 (53.7%), respectively. No differences were found among the three periods.

Conclusions: Owing to the technical improvements over time, pure laparoscopic living donor hepatectomy is currently feasible and safe even for donors with anatomical variations.

Keywords: Donor hepatectomy; liver transplantation; laparoscopy

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Introduction

Living donor liver transplantation (LDLT) is a treatment option for end-stage liver disease. In the LDLT era, donor operations should be viewed from a different perspective compared with other operations because it is performed on healthy individuals. Therefore, the safety of the donor is paramount, but the minimisation of postoperative wounds and pain reduction is also important. For these reasons, the donor operation can be considered via the laparoscopic approach. This was first introduced by Cherqui *et al.* in 2002, with a donor hepatectomy performed to procure a left lateral graft (1). Since then, there has been remarkable progress in the laparoscopic approach to donor hepatectomy (1-5). There are multiple advantages in the laparoscopic

approach for liver resection, including reduction in the duration of in-hospital stay and improvement of cosmetic and postoperative outcomes (6-9). Some large centres have presented studies on laparoscopic donor hepatectomy and surgical outcomes (10-14). However, further research on the safety and feasibility is needed. Open donor hepatectomy is still a preference in many centres worldwide, while some hospitals have just recently begun laparoscopic donor hepatectomy.

In 2015, our centre operated the first case of pure laparoscopic donor hepatectomy (PLDH), since then, we have performed about 350 cases of PLDH from 2015 to 2019, of which most were right hemihepatectomy. We presented the first 55 cases of pure laparoscopic living donor right hemihepatectomy (PLDRH) and subsequently presented several papers about the experience and operative techniques of PLDH (15-18); this is the largest series of PLDRH in a single-centre, worldwide. The outcomes of PLDRH in our centre have improved over time.

This study aimed to evaluate the surgical outcomes with an increase in the PLDRH performance experience and to identify areas of improvement. We compared the differences between 300 cases that were divided chronologically into three periods of 100 cases each. Another purpose of this study was to determine whether surgical outcomes vary according to anatomical variation and whether there were relative contraindications for PLDRH.

We present the following study in accordance with the STROBE reporting checklist (available at http://dx.doi.org/10.21037/atm-20-6886).

Methods

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Institutional Review Board of the Seoul National University Hospital (SNUH) (IRB No. 2007-052-1140). Because of the retrospective nature of the study, the requirement for informed consent was waived.

Patient and data

Between December 2015 and May 2019, a total of 313 medical records of donors who underwent PLDH by two surgeons at SNUH were reviewed retrospectively. Among them, 300 donors underwent PLDRH, which included pure laparoscopic donor extended right hemihepatectomy. We divided the patients into three periods of 100 cases in chronological order. We reviewed the dynamic computed tomography (CT) and magnetic resonance imaging (MRI) of all donors. The estimated total liver and graft volumes were measured using CT. Postoperative complications of donors were graded using the Clavien-Dindo classification (19). Early complications were in-hospital complications occurring within 30 days of liver transplantation. The blood loss was calculated as change in Δhemoglobin (Hb)% = [(pre-operative Hb – postoperative Hb)/pre-operative Hb] × 100. The estimated blood loss was evaluated by an anesthesiologist who participated in the operation and measured the estimated blood loss by the amount of effluent in the suction bottle and the weight of the gauze used during the operation.

Donor selection criteria

The donor selection process and criteria at SNUH have been described in detail in previous publications (15-17). All donors were conducted multidisciplinary evaluation preoperatively. Pre-operative imaging for donor anatomical evaluation was conducted using dynamic multiphasic hepatic CT and MRI with PrimovistTM. During the start of the PLDH program, the initial 17 cases selected were those with classical vascular and biliary anatomy with no anatomical variation. After the introduction of the use of intraoperative indocyanine green (ICG) near-infrared fluorescence camera system in March 2016, the anatomical variation of the liver of the donor was no longer considered a contraindication. After that, we only performed open donor hepatectomy either when the donor wanted to undergo open donor hepatectomy at their request or laparoscopic system was not available in the center.

Surgical procedure

Our institution previously described a detailed surgical procedure for PLDRH (15-17). The donor was placed in lithotomy position. After the umbilical port was inserted, intraperitoneum was inflated under 12 mmHg for pneumoperitoneum. Then, four working ports were inserted. The 3D flexible laparoscopic scope was used during the operation. The right liver was mobilized with the energy device. The hanging maneuver was performed with a Nelaton tube through the avascular plane between the liver and the inferior vena cava. We used cavitron ultrasonic suction aspirator (CUSA®, Valleylab, Inc., Boulder, CO, USA) for parenchymal dissection. Before

Table 1 Demographics of donor

Variables	Total	Period 1	Period 2	Period 3	P value
Patients, n	300	100	100	100	–
Age, mean ± SD (year)	33.0±10.5	33.8±11.8	31.8±10.3	33.3±9.2	0.39
Gender (M:F)	159:141	56:44	59:41	44:56	0.08
BMI, mean ± SD (kg/m^2)	23.5±3.3	23.7±3.2	23.8±3.6	23±3.2	0.16
Relationship, n (%)					0.12
Parent	4 (1.3)	2 (2.0)	1 (1.0)	1 (1.0)	
Offspring	213 (71.0)	63 (63.0)	75 (75.0)	75 (75.0)	
Spouse	42 (14.0)	20 (20.0)	10 (10.0)	12 (12.0)	
Sibling	29 (9.7)	10 (10.0)	10 (10.0)	9 (9.0)	
Other relative	12 (4.0)	5 (5.0)	4 (4.0)	3 (3.0)	
Pre-operative blood test, mean ± SD					
Hb (g/dL)	14.0±1.4	14.3±1.5	13.9±1.4	13.7±1.4	0.02
Total bilirubin (mg/dL)	0.6±0.6	0.6±0.3	0.6±0.9	0.5±0.2	0.40
AST (IU/L)	18.6±4.8	18.2±5.1	19.4±7.4	18.2±4.4	0.22
ALT (IU/L)	18.3±10.7	17.6±9.2	19.8±12.6	17.4±9.9	0.22
Graft type, n (%)					0.13
Right liver	274 (91.3)	95 (95.0)	92 (92.0)	87 (87.0)	
Extended right liver	26 (8.7)	5 (5.0)	8 (8.0)	13 (13.0)	

SD, standard deviation; BMI, body mass index; Hb, hemoglobin; AST, aspartate aminotransferase; ALT, alanine aminotransferase.

dissection of the right hepatic ducts, real-time ICG near-infrared fluorescence cholangiography was used to clearly identify the division of the right hepatic ducts. The right hepatic artery was ligated with Hem-O-Lok clips (Weck Closure System, Research Triangle Park, NC, USA) and divided. Then, the right portal vein (RPV) branches, the right hepatic vein and the inferior vena cava were resected each with endostapler in turn. The Pringle maneuver was not routinely performed.

Statistical analysis

All statistical analyses were performed using SPSS software version 22.0 for Windows (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation and compared using the Student's *t*-test. Categorical variables were expressed as numbers with percentages and compared using the χ^2 test or Fisher's exact test.

Results

Demographics of donors who underwent PLDRH (Table 1)

From November 2015 to May 2019, a total of 300 donors underwent PLDRH at SNUH. Their mean age was 33.0±10.5 years, and 159 (53.0%) were male. Of the 300 live donors, 213 (71.0%) were offspring donating to their parents. There were no differences between the three periods in terms of age, sex, body mass index (BMI), relationship, and pre-operative blood test except for haemoglobin. The mean haemoglobin level decreased significantly over the periods from 14.3±1.5 to 13.9±1.4 g/dL, and eventually, 13.7±1.4 g/dL as the time-period progressed chronologically (P=0.02).

Perioperative data of donors who underwent PLDRH (Table 2, Figure 1)

In the operative data of the donor, the mean operation time

Table 2 Perioperative outcomes of donor

Variables	Total	Period 1	Period 2	Period 3	P value
Total operative time, mean ± SD (min)	267.8±74.2	318.9±62.2	256.7±71.4	227.7±57.4	<0.01
Time to extraction of graft, mean ± SD (min)	204.8±56.0	234.0±45.2	202.8±50.9	177.6±56.7	<0.01
Blood loss, mean ± SD (mL)	261.5±209.8	419.7±196.5	198.9±197.2	166.0±130.0	<0.01
Hospital stay (day)	7.4±2.6	8.1±2.0	7.3±3.1	6.9±2.4	<0.01
Rehospitalization, n (%)	7 (2.3)	3 (3.0)	3 (3.0)	1 (1.0)	0.56
Postoperative blood tests, mean ± SD					
Hb (g/dL)					
Lowest	11.6±1.4	11.8±1.4	11.5±1.5	11.5±1.2	0.15
Delta Hb (%)	16.5±7.0	16.9±7.1	16.8±8.0	15.8±5.6	0.49
POD 1 week	12.5±1.4	12.6±1.5	12.4±1.4	12.4±1.4	0.57
POD 1 month	13.5±1.6	13.7±1.7	13.5±1.6	13.3±1.4	0.17
Total bilirubin (mg/dL)					
Peak	4.1±1.8	3.8±1.8	4.4±2.1	4.1±1.5	0.10
POD 1 week	1.4±0.8	1.3±0.9	1.5±0.8	1.4±0.7	0.08
POD 1 month	0.8±0.6	0.7±0.3	0.9±1.0	0.8±0.3	0.22
AST (IU/L)					
Peak	233.6±82.4	233.2±83.5	220.5±77.9	217.2±85.7	0.35
POD 1 week	48.1±22.3	49±28.0	47.1±17.6	48.2±20.2	0.84
POD 1 month	26.5±9.5	25.1±10.0	26.9±7.8	27.6±10.4	0.15
ALT (IU/L)					
Peak	230.2±85.6	239.6±94.4	229.5±80.2	221.5±81.5	0.33
POD 1 week	74.5±32.0	71.9±37.4	72.7±26.2	79.0±31.2	0.23
POD 1 month	29.9±22.3	28.9±28.2	30.6±16.4	30.2±20.7	0.85

SD, standard deviation; Hb, hemoglobin; POD, postoperative day; AST, aspartate aminotransferase; ALT, alanine aminotransferase.

was 267.8±74.2 min, and the mean time to liver extraction was 204.8±56.0 min. The mean amount of blood loss was 261.5±209.8 mL during operation, and no intraoperative transfusion was required. The mean length of hospital stay was 7.4±2.6 days, and none of the donors was admitted to the intensive care unit. The mean operation time for periods 1, 2, and 3 were 318.9±62.2, 256.7±71.4, and 227.7±57.4 min, respectively, with a significant decrease (P<0.01) as the time-period progressed. The time to extraction of the liver graft (234.0±45.2, 202.8±50.9, and 177.6±56.7 min, P<0.01); blood loss (419.7±196.5, 198.9±197.2, and 166.0±130.0 mL, P<0.01); and hospital stay (8.1±2.0, 7.3±3.1, and 6.9±2.4 days, P<0.01) decreased as the time-period progressed. There was no statistically significant difference in terms of postoperative blood tests, including ΔHb.

Postoperative complications in the donor (Table 3)

The total complication rate was 20/300 (6.7%), and the number of major complications (Clavien-Dindo grade III or above) was 8/300 cases (2.7%). Four complications were of the bile duct, three of the portal veins, and one of intra-abdominal bleeding. Four cases required surgical intervention. When the major complications were compared as the time-period progressed, there were three in period 1, two in period 2, and one in period 3. In terms

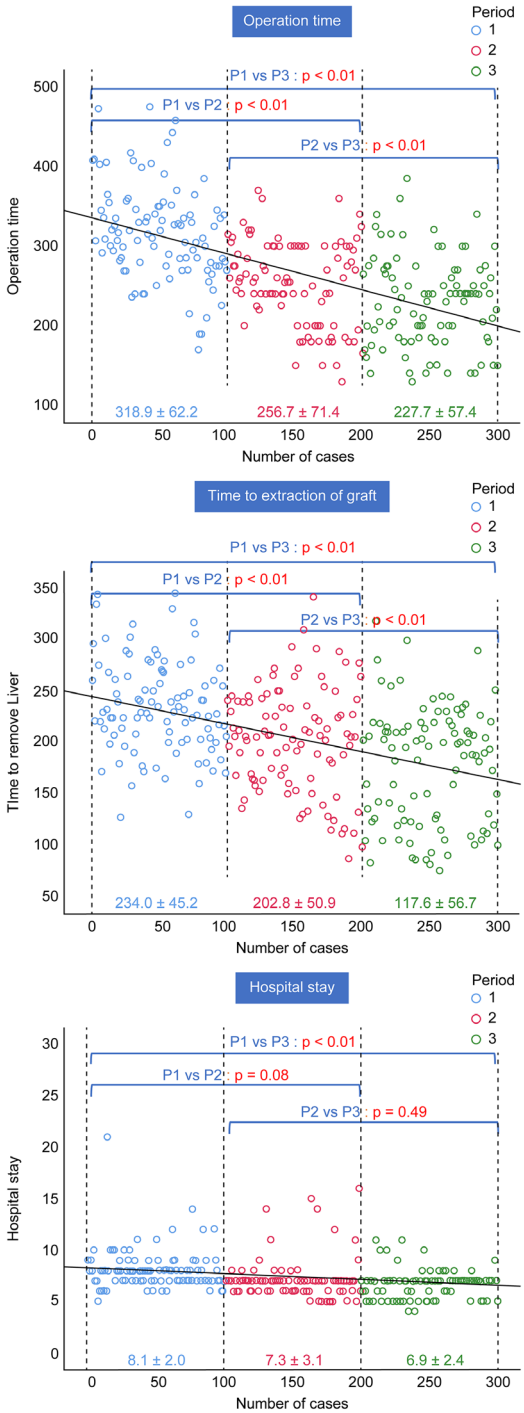

Figure 1 Operative outcomes of donor. The mean operation time for periods 1, 2, and 3 were 318.9±62.2, 256.7±71.4, and 227.7±57.4 min, respectively, with a significant decrease (P<0.01) as the time-period progressed. The time to extraction of the liver graft (234.0±45.2, 202.8±50.9, and 177.6±56.7 min, P<0.01); and hospital stay (8.1±2.0, 7.3±3.1, and 6.9±2.4 days, P<0.01) decreased as the time-period progressed.

of the postoperative complications of the donor, there was no difference between the three periods (P=0.14).

Graft anatomy of the donor (Table 4)

We defined the predicted multiple portal veins as portal vein trifurcations or portal vein stumps less than 10 mm in the CT scan. In addition, the predicted multiple bile ducts and hepatic arteries were also defined as trifurcations or stumps less than 5 mm. We predicted 31 (10.3%) cases of multiple portal vein orifices and 7 (2.3%) cases of multiple hepatic arteries from the pre-operative CT. There were 179 (59.7%) cases of multiple bile duct orifices seen on the pre-operative MRI. In the actual grafts, 32 (10.7%) had multiple portal veins, and 11 (3.7%) had multiple hepatic arteries. There were 161 (53.7%) grafts with multiple bile duct orifices. In terms of anatomical variations, multiple portal vein orifices were increased especially in period 3 (17, 17.0%) compared with 8 (8.0%) and 7 (7.0%) in period 1 and 2 (P=0.04). However, there were no statistical differences among periods in terms of multiple bile ducts and hepatic arteries in the predicted and actual grafts.

Demographics of recipients who underwent PLDRH (Table 5)

Among recipients, the mean age was 54.6±10.9 years, of which 222 (74.0%) were male. The most common aetiology for liver cirrhosis of the recipient was hepatitis B (60.3%). A total of 187 patients (62.3%) had hepatocellular carcinoma (HCC). The mean model for end-stage liver disease (MELD) score of recipients was 14.7±6.2, and 17.7% of the donor-recipient pairs were ABO incompatible. There was a gradual decrease in the MELD score of recipients (17.7±4.8, 14.0±6.3, and 12.4±6.2, P<0.01). The number of cases of ABO-incompatible liver transplants was statistically different between the three periods, especially high in period 3 (15, 11, and 27, P=0.01). There was no statistical difference between the periods in age, BMI, underlying disease, and the proportion of HCC cases.

Early complications of recipients who underwent LDLT (Table 6)

Of the total recipients, 130 (43.3%) had early complications, which were defined as postoperative complications occurring within 30 days. Biliary complications were the most common, accounting for 25 cases (8.3%). Hepatic and

Table 3 Postoperative complications of donor

Variables	Total	Period 1	Period 2	Period 3	P value
Complications, n (%)	20 (6.7)	10 (10.0)	7 (7.0)	3 (3.0)	0.14
Grade I	4 (1.3)	3 (3.0)	0 (0.0)	1 (1.0)	0.17
Wound problem	3 (1.0)	2 (2.0)	0 (0.0)	1 (1.0)	
Pleural effusion	1 (0.3)	1 (1.0)	0 (0.0)	0 (0.0)	
Grade II	8 (2.7)	4 (4.0)	3 (3.0)	1 (1.0)	0.41
Intra-abdominal fluid collection requiring antibiotics	6 (2.0)	3 (3.0)	2 (2.0)	1 (1.0)	
Portal vein partial thrombus requiring anticoagulation	1 (0.3)	1 (1.0)	0 (0.0)	0 (0.0)	
Pulmonary thromboembolism with ovarian vein thrombosis requiring anticoagulation	1 (0.3)	0 (0.0)	1 (1.0)	0 (0.0)	
Grade IIIa	4 (1.3)	1 (1.0)	2 (2.0)	1 (1.0)	1.00
Biliary leakage requiring endoscopic stenting	2 (0.7)	1 (1.0)	0 (0.0)	1 (1.0)	
Portal vein stenosis requiring interventional therapy	2 (0.7)	0 (0.0)	2 (2.0)	0 (0.0)	
Grade IIIb	4 (1.3)	2 (2.0)	2 (2.0)	0 (0.0)	0.24
Biliary stricture requiring operation	2 (0.3)	1 (1.0)	1 (1.0)	0 (0.0)	
Intra-abdominal bleeding requiring operation	1 (0.3)	1 (1.0)	0 (0.0)	0 (0.0)	
Portal vein stenosis requiring open conversion	1 (0.3)	0 (0.0)	1 (1.0)	0 (0.0)	

Table 4 Graft anatomy of donor

Variables	Total	Period 1	Period 2	Period 3	P value
Preoperative predicted graft					
Predicted multiple poral vein orifices in CT (%)	31 (10.3)	8 (8.0)	7 (7.0)	16 (16.0)	0.07
Predicted multiple hepatic artery orifices in CT (%)	7 (2.3)	3 (3.0)	1 (1.0)	3 (3.0)	0.56
Predicted multiple bile duct orifices in MRI (%)	179 (59.7)	61 (61.0)	63 (63.0)	55 (55.0)	0.49
Postoperative actual graft					
Multiple portal vein orifices	32 (10.7)	8 (8.0)	7 (7.0)	17 (17.0)	0.04
Multiple hepatic artery orifices	11 (3.7)	5 (5.0)	2 (2.0)	4 (4.0)	0.52
Multiple bile duct orifices	161 (53.7)	60 (60.0)	52 (52.0)	49 (49.0)	0.27

CT, computed tomography; MRI, magnetic resonance imaging.

portal veins complication rate was 14 (4.7%), and the total acute cellular and antibody-mediated rejection rate was 20 (6.7%). The 30-day mortality rate was 2.7%. There was no difference between periods in terms of early complications of the recipient and 30-day mortality rate.

Discussion

Since the initiation of PLDH in SNUH in 2015, there has been a gradual increase in the proportion of donor hepatectomies performed laparoscopically compared with those performed using the open approach, from 78.1%, to 86.7%, and 88.2% in 2016, 2017, and 2018, respectively. Apart from the initial cases, there are currently no absolute contraindications to PLDRH. However, as PLDH is still a relatively novel procedure, informed consent was obtained from the patient about the potential risks and benefits of PLDH versus the open approach. Some donors opted for

Table 5 Demographics of recipient

Variables	Total	Period 1	Period 2	Period 3	P value
Patients, n	300	100	100	100	–
Age, mean ± SD (year)	54.6±10.9	53.0±10.2	54.5±10.8	56.3±11.5	0.10
Gender (M:F)	222:78	78:22	69:31	75:25	0.33
BMI, mean ± SD (kg/m^2)	23.8±3.4	23.9±3.3	24.0±3.5	23.6±3.4	0.75
Underlying liver disease, n (%)					0.45
Hepatitis B	181 (60.3)	68 (68.0)	56 (56.0)	57 (57.0)	
Alcohol	61 (20.3)	16 (16.0)	23 (23.0)	22 (22.0)	
Hepatitis C	15 (5.0)	5 (5.0)	5 (5.0)	5 (5.0)	
NBNC liver cirrhosis	8 (2.7)	3 (3.0)	4 (4.0)	1 (1.0)	
Sclerosing cholangitis	7 (2.3)	2 (2.0)	2 (2.0)	3 (3.0)	
Autoimmune hepatitis	5 (1.7)	2 (2.0)	3 (3.0)	0 (0)	
NASH	4 (1.3)	0 (0)	0 (0)	4 (4.0)	
Overlap syndrome	3 (1.0)	0 (0)	1 (1.0)	2 (2.0)	
HBV + HCV	3 (1.0)	1 (1.0)	2 (2.0)	0 (0)	
Etc.	13 (4.3)	3 (3.0)	4 (4.0)	6 (6.0)	
Hepatocellular carcinoma, n (%)	187 (62.3)	71 (71.0)	59 (59.0)	57 (57.0)	0.09
MELD score, mean ± SD	14.7±6.2	17.7±4.8	14.0±6.3	12.4±6.2	<0.01
ABO incompatibility, n (%)	53 (17.7)	15 (15.0)	11 (11.0)	27 (27.0)	0.01

SD, standard deviation; BMI, body mass index; NASH, nonalcoholic steatohepatitis; HBV, hepatitis B virus; HCV, hepatitis C virus; MELD, model for end-stage liver disease score.

Table 6 Early complications of recipient

Variables	Total	Period 1	Period 2	Period 3	P value
Total complications	130 (43.3)	44 (44.0)	39 (39.0)	47 (47.0)	0.06
Complication types, n (%)					–
Intra-abdominal bleeding	18 (6.0)	5 (5.0)	4 (4.0)	9 (9.0)	
Intra-abdominal fluid collection	2 (0.7)	0 (0.0)	1 (1.0)	1 (1.0)	
Wound complication	19 (6.3)	5 (5.0)	5 (5.0)	9 (9.0)	
Hepatic artery complication	8 (2.7)	3 (3.0)	3 (3.0)	2 (2.0)	
Hepatic vein & portal vein complication	14 (4.7)	5 (5.0)	2 (2.0)	7 (7.0)	
Biliary complication	25 (8.3)	8 (8.0)	9 (9.0)	8 (8.0)	
Acute cellular rejection	15 (5.0)	6 (6.0)	8 (8.0)	1 (1.0)	
Antibody-mediated rejection	5 (1.7)	0 (0.0)	0 (0.0)	5 (5.0)	
Cardiac complication	7 (2.3)	4 (4.0)	1 (1.0)	2 (2.0)	
Neurological complication	6 (2.0)	1 (1.0)	3 (3.0)	2 (2.0)	
Renal complication	4 (1.3)	4 (4.0)	0 (0.0)	0 (0.0)	
Sepsis	6 (2.0)	2 (2.0)	3 (3.0)	1 (1.0)	
Deep vein thrombosis	1 (0.3)	1 (1.0)	0 (0.0)	0 (0.0)	
30-day mortality, n (%)	8 (2.7)	2 (2.0)	4 (4.0)	2 (2.0)	0.60

open donor hepatectomy after counselling. Other reasons why the open approach was selected include logistical issues such as a non-functioning ICG system or 3D laparoscope. The open method was also utilised when the specialised assistant managing the 3D laparoscope was unavailable.

As the time-period progressed, there was a decrease in the operation time, time to extract the liver graft, and the length of hospital stay for the donor (*Figure 1*). SNUH previously reported that the operation time for PLDRH was longer than that for open donor right hepatectomy (15,17). In a study comparing open donor hepatectomy versus the 55 early cases of PLDRH, the operation time of conventional donor right hepatectomy (CDRH) was significantly shorter than that of PLDRH (280.0±39.9 versus 330.7±49.5 min, P<0.001). However, the mean operation time of period 3 in our current study was 227.7±57.4 min, which is faster than that of the CDRH group from the previous study. This demonstrated the improvement in technical competency as we overcame the learning curve.

The safety of the donor is paramount in PLDRH. All donors who underwent PLDRH in SNUH did not require admission into the intensive care unit or intraoperative transfusion of blood. Based on our results, the overall complication rate of the donor was 6%, and the complication rate of those with Clavien-Dindo grade III or higher was 2.7%. In period 1, we experienced three cases of major complications; in period 2, we experienced four cases of major complications. However, in period 3, the major complication was reduced to just one case. In four of the major complications, surgical interventions were required. Laparoscopic surgical haemostasis was performed in one case of postoperative intra-abdominal bleeding at the site of the small short hepatic vein. There was one case of common bile duct injury and division of the bile duct, which required a laparoscopic duct-to-duct anastomosis. One developed a biliary stricture during postoperative care. We performed open minilaparotomy with opening and resuturing the bile duct suture site. The open approach was adopted for one case of left portal vein stenosis. However, all donors recovered completely without further problems and were discharged.

In our series of 300 cases, 53.7% had bile duct variation. Bile duct complications are the Achilles' heel of liver transplantation, as there are not only anatomical considerations for the donor and long-term surgical outcomes for the recipient. There was a total of four cases of bile duct complications, which were Clavien-Dindo grade III and above. Two of the cases had multiple bile duct openings. Apart from the initial 17 cases, all other cases used ICG for the identification of the biliary anatomy. The introduction of the ICG camera enhanced bile duct division while minimising excessive dissection and potential injury to the left bile duct, even if there is an anatomical variation of bile duct (20).

We predicted multiple bile duct orifices in 179 out of 300 (59.7%) cases based on pre-operative imaging; however, the actual number of grafts with multiple bile ducts was 161 (53.7%). In period 1, 61 multiple bile duct orifices were predicted, and in practice, multiple orifices were observed in 60 grafts. However, in period 2, 63 grafts were predicted, but 52 were observed, and in period 3, 55 grafts were expected, but 49 were observed. Thus, fewer actual multiple orifices than the predictions were observed in practice. From a complication point of view, there were donor bile duct complications of Clavien-Dindo grade III or higher in each period: 2 in period 1 and 1 each in periods 2 and 3. Thus, the operator can make fewer opening grafts while maintaining the safety of the donor even though a short stump is predicted as the skill level increases over time. In addition, if the bile duct stump is expected to be short, instead of double clipping the left bile duct stump of the donor, we performed single clipping and sutured with prolene 6-0 on the donor stump. This method of securing the bile duct stump and preventing multiple orifices was used for period 3. Due to the increase in proficiency and technological advancement over time, although not statistically significant, the actual number of grafts with multiple bile duct orifices decreased to 60, 52, and 49 for periods 1–3, respectively.

There were 3 cases of portal vein complications of Clavien-Dindo grade III and above, none of which had multiple portal veins. Portal vein complications occurred in 1 and 2 cases in periods 1 and 2, respectively. However, we performed 17 donor operations for which multiple portal veins were predicted in period 3, compared to 8 and 7 cases in periods 1 and 2, respectively, but no portal vein complications occurred. We had previously presented several papers on specific techniques concerning PLDRH for grafts with anatomical variations (21-23). Thus, anatomical variations can pose a technical challenge to the operating surgeon but do not affect the safety and feasibility of PLDRH.

This study had several limitations. First, this was a retrospective study, although there are no prospective studies to date. Being the largest series reported globally in a single-centre, this study is still invaluable because

it summarises the collective experience of the pioneers of PLDRH. Second, the surgeons involved in this study are extremely experienced in the field of LDLT who had a collective experience of over 500 cases of open donor hepatectomies. Therefore, these results may not be generalisable or replicable for other centres, as this is a highly specialised procedure that has a steep learning curve. Third, we were unable to conclude that PLDRH is safer or superior to CDRH using the data from this study, as this is a single-arm descriptive study and not a randomised controlled trial. Previously published papers on the outcomes of open living donor hepatectomy reported a complication rate of Clavien-Dindo grade III and above at about 4–13% (24-26). Most of the cases in the studies utilised a left lateral graft. In our series, we evaluated the surgical outcomes of using only right lobe grafts, which is technically more challenging than using left lateral grafts. Further comparative studies with well-established control groups, such as a randomised controlled trial or propensity score matching, should be conducted. Fourth, these cases were performed recently with a relatively short follow-up period. Longer follow-up duration of both the donors and recipients is required to ascertain the long-term outcomes.

Conclusions

In conclusion, owing to recent and ongoing technical improvements, pure laparoscopic living donor hepatectomy is presently feasible and safe even for donors with anatomical variations.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This study was approved by the Institutional Review Board of the Seoul National University Hospital (IRB No. 2007-052-1140). Because of the retrospective nature of the study, the requirement for informed consent was waived.

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