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Revised Living Donor Liver Transplantation：Preliminary Outcomes of Recently Introduced Surgical Techniques

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ABSTRACT

Introduction：Surgical techniques for living donor liver transplantation (LDLT) have been refined and standardized worldwide. We changed the surgical plan and performed LDLTs with right lobe grafts using efficient techniques.

Methods：The study included 31 patients who had undergone LDLT for end-stage liver disease from 2007 through 2022. The study period was divided into era 1 (2007-2019, $n = 24$) and era 2 (2020-2022, $n = 7$). In era 2, right-lobe graft was selected if the graft-to-recipient weight ratio was greater than 0.8%. The en-bloc sharp division of the arterial-biliary bundle at the high-hilar level was introduced for recipient surgery in era 2.

Results：In era 2, a right-lobe graft was used for all LDLTs, and the mean estimated graft volume and the graft-to-recipient weight ratio were greater than those of era 1 (482 vs. 805 ml, $p < 0.001$, and 0.98% vs. 1.20%, $p = 0.002$, respectively). In the era 2, both donor and recipient operative times were shorter than in era 1 (481 vs. 237 minutes, $p < 0.001$, and 820 vs. 457 minutes, $p < 0.001$, respectively) and no splenectomy was performed.

Conclusion：We made the surgical time shorter and stable with no short-term mortality of recipients, with recently introduced surgical techniques of recipient and donor surgery.

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Key words：living donor liver transplantation, hilar dissection, complication, graft-recipient weight ratio, splenectomy

Introduction

Living donor liver transplantation (LDLT) is a standard option for treating end-stage liver disease. Short-term graft outcomes after LDLT have improved significantly because of the refined graft selection process and improvements of perioperative management and surgical techniques[1-3]. Surgical techniques in LDLT surgery have been refined and standardized worldwide[4,5]. Of note, minimal hilar dissection with the subtraction method in donor surgery and the en-bloc sharp division of the arterial biliary bundle at the high hilar level in recipient surgery have shortened operative time and reduced biliary complications in both donors and recipients[6,7].

The required graft volume for the recipient has been evaluated by two ways including the graft-to-recipient weight ratio (GRWR) and the graft weight to standard liver weight (GW/SLW)[8]. In previous studies, minimum accept-

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able values were 0.6% to 0.8% for the GRWR and 30% to 40% for the GW/SLW ratio[8-10]. Because a greater percentage of recipients have obesity, we have changed our graft selection criteria from the GW/SLW ratio to the GRWR[11].

In the present retrospective study, we investigated the surgical and postoperative outcomes of 7 consecutive LDLTs with right lobe grafts performed with newly introduced techniques.

Patients and Methods

Patient selection

The participants of this retrospective study were patients who had undergone LDLT for end-stage liver disease at the Department of Surgery, The Jikei University Hospital, Tokyo, Japan, from January 2007 through July 2020. Thirty-one patients were enrolled. The study period was divided into "era 1" of 2007 through 2019 and "era 2" of 2020 through 2022. Data on clinical information, operative and pathological finding, and the postoperative course was collected from medical records. Patients were followed up until death or until March 1, 2023, the end of follow-up period. This study was approved by the Ethics Committee of The Jikei University School of Medicine for Biomedical Research (#27-177).

Donor selection

In era 1, donor selection criteria were as follows : an adult 65 years or younger, good general condition, a partial liver volume of more than 35% of the standard liver wight (SLW) for the recipient and the remnant liver volume of more than 30% of the donor's total liver volume on preoperative volumetry with computed tomography, and no severe liver steatosis (< 30%)[12]. In era 2, the graft selection process was changed, on the basis of a previous study[11], with a GRWR > 0.8% and a remnant liver volume > 30% of the donor's total liver volume.

Surgical procedure in donor hepatectomy

In era 2, after the donor had been taken to the operating room, general anesthesia was administered and was followed by placement of multiple lines. The LDLT donor surgery began with an upper midline incision[13], after which right lobe mobilization and minimal hilar dissection were performed[6]. Parenchymal resection was performed along the demarcation line to the inferior vena cava (IVC) under a hanging maneuver to design a straight line (Fig. 1A). After division and closure of the right hepatic duct with the assistance of real-time cholangiography (Fig. 1B), the right hepatic artery was ligated and sharply cut. The right portal vein and the right hepatic vein were both stapled (Proximate® TX-30V, Johnson & Johnson, Tokyo, Japan) and divided, and the right lobe graft was procured. In era 1 (2007-2019), skin incision was upper midline incision with right subcostal incision or Mercedes-Benz incision. Liver parenchymal resection was performed along the demarcation line. A cholangiogram was performed repeatedly to determine the division point of the bile duct. The stump of the portal vein and the hepatic vein were closed using a polypropylene suture. In era 1, 5 surgeons were involved in donor surgery as operators, while 1 surgeon was involved in donor surgery in era 2.

Surgical procedures in recipient surgery

In era 2, after the recipient had arrived in the operating room, general anesthesia was administered and multiple lines were placed. The recipient surgery started with the initial procedure of the Pringle maneuver to obstruct the hepatic inflow. Under bloodless surgical conditions, cholecystectomy and portal vein isolation were followed by the en-bloc sharp division of the arterial biliary bundle at the high-hilar level (Fig. 1C-D), which was modified from the original method[7]. Thereafter, the left and right portal veins were isolated and divided. Liver mobilization was then performed. The hepatic venous system was divided via staples (Powered Echelon Flex® 60 white, Johnson & Johnson), and the total hepatectomy was completed. Then, after the arterial–biliary bundle had been clamped, the left, middle, and right hepatic arteries were sharply isolated via scissors. Bile duct stump plasty and hemostasis were also performed under intermittent inflow control. After the right lobe graft was flushed and placed into the recipient, venous and portal anastomoses were performed and followed by reperfusion. Arterial reconstruction was performed under a microscope, and biliary reconstruction was performed as previously reported[14].

In era 1, to maintain hepatic inflow and outflow, graft procurement was performed and followed by hilar dissection and liver mobilization. Venous, portal, arterial, and biliary reconstructions were the same as those in era 2. In era

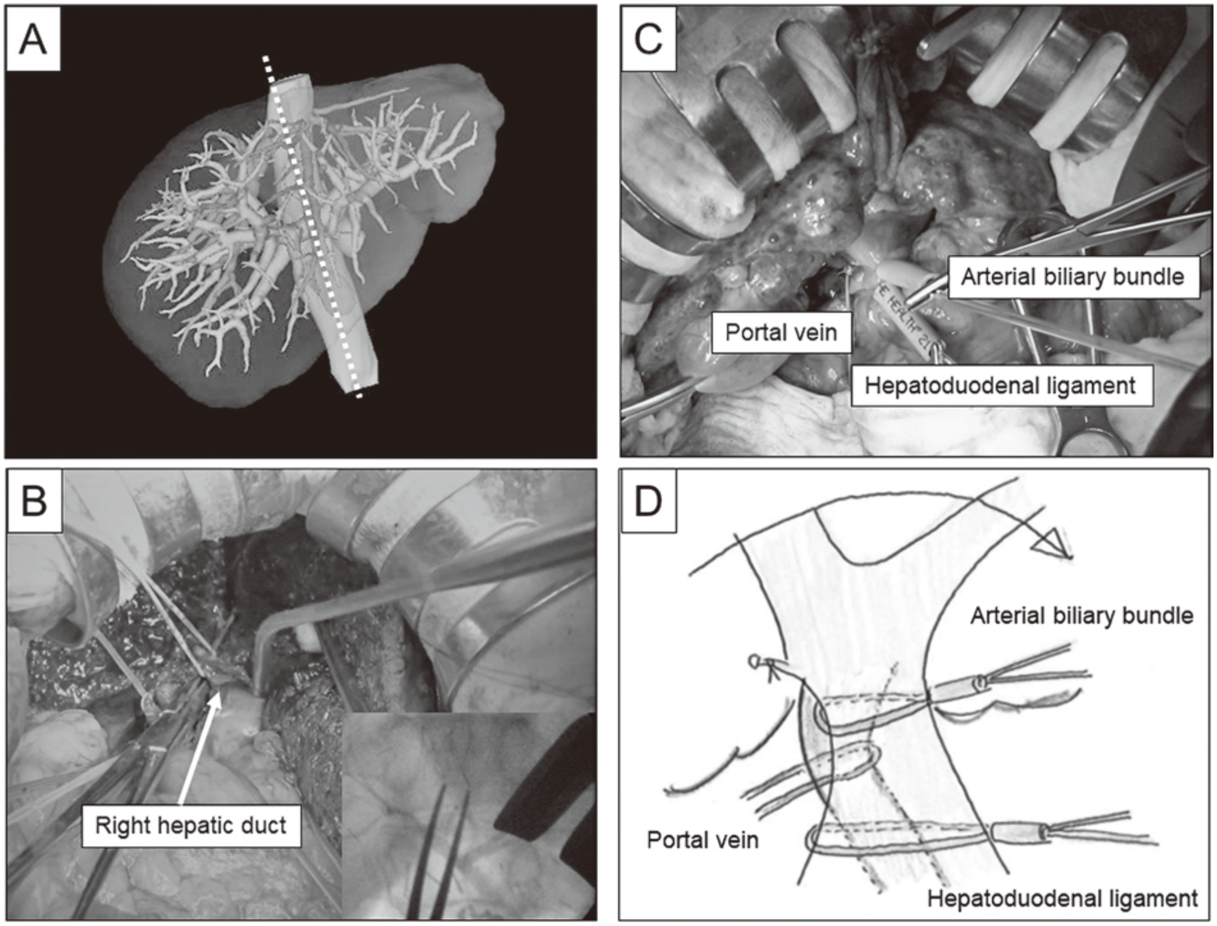

Fig. 1. (A) Preoperative 3-dimensional imaging for parenchymal resection along the demarcation line to the inferior vena cava. (B) The division of the right hepatic duct with the assistance of real-time cholangiography. (C) The en-bloc sharp division of the arterial biliary bundle at the high hilar level. (D) Schematic diagram of the high hilar dissection.

1, 4 surgeons were involved in recipient surgery as operators, while in era 2, 2 surgeons were involved in recipient surgery.

Statistical analysis

All statistical analyses were conducted with the software program IBM® SPSS Statistics, version 25.0 (IBM Japan, Tokyo, Japan), and all p-values are two-sided. The two-sided α level of 0.05 was used. Data are expressed as a median, range, or ratio. Continuous and categorical variables were compared using the Mann-Whitney U-test or Chi-square test, as appropriate.

Results

Donor characteristics and surgical outcomes

As expected, a right lobe graft was chosen for all recipients in era 2 (2020–2022 ; $p = 0.004$), and estimated graft volume (805 ml vs. 482 ml, $p < 0.001$) and the GRWR (1.20% vs. 0.98%, $p = 0.002$) were significantly greater in era 2 compared with those in era 1 (2007-2019 (Table 1). Operation time was significantly shortened (237 minutes) in era 2, owing to methods introduced, than in era 1 (482 minutes, $p < 0.001$; Figure 2A). Both intraoperative blood loss (110 g vs. 275 g, $p = 0.054$) and the rate of postoperative complications (Clavien-Dindo grade 3 or greater ; 0% vs 9%, $p = 0.054$; Figure 2A) were lower in era 2 than in era 1 but not to a significant degree. There was no donor mortality both in eras 1 and 2.

Recipient characteristics and surgical outcomes

Recipients were older in era 2 (61 years old) than in era 1 (53 years old, $p = 0.05$; Table 2). Operation time (457 minutes vs. 820 minutes, $p < 0.001$), intraoperative blood

Table 1. Comparison of donor and recipient characteristics and outcomes between eras 1 and 2

Variables	Era 1 : 2007-2019 (n = 24)	Era 2 : 2020-2022 (n = 7)	p-value
Donors			
Age (years)	43 (18-66)	38 (27-53)	0.56
Sex, male	13 (54%)	3 (43%)	0.60
Right lobe graft	9 (38%)	7 (100%)	0.004
Estimated graft volume (ml)	482 (330-698)	805 (608-865)	<0.001
Estimated GRWR (%)	0.98 (0.62-1.25)	1.20 (0.98-1.54)	0.002
Duration of operation (min)	481 (288-711)	237 (219-283)	<0.001
Intraoperative blood loss (g)	275 (10-2,330)	110 (50-230)	0.054
Postoperative complications (Clavien-Dindo grade 3 or greater)	9 (38%)	0 (0%)	0.054
Postoperative hospital stay (days)	12 (7-38)	10 (8-24)	0.27
Recipients			
Age (years)	53 (12-65)	61 (40-68)	0.05
Sex, male	9 (38%)	4 (57%)	0.35
Model for end-stage liver disease score	17 (4-33)	12 (8-22)	0.23
Duration of operation (min)	820 (650-1,130)	457 (342-558)	<0.001
Intraoperative blood loss (g)	2,185 (450-24,550)	1,355 (970-2,200)	0.043
Cold ischemia time (min)	124 (62-279)	84 (41-190)	0.048
Warm ischemia time (min)	43 (30-103)	32 (19-48)	0.003
Splenectomy	18 (75%)	0 (0%)	<0.001
Total bilirubin on postoperative day 14 (mg/dl)	3.1 (0.7-27.2)	1.2 (0.6-2.2)	0.013
Postoperative complications (Clavien-Dindo grade 3 or greater)	7 (29%)	1 (14%)	0.43
Postoperative hospital stay (days)	33 (14-146)	16 (13-56)	0.10
Bile duct stricture	6 (25%)	0 (0%)	0.076
Six-month survival (%)	100	100	NA

Values given as median, range, or ratio. GRWR, graft-to-recipient weight ratio

loss (457 g vs. 820 g, p = 0.043), cold ischemia time (84 minutes vs. 124 minutes, p = 0.048), and warm ischemia time (32 minutes vs. 43 minutes, p = 0.003) were significantly lower in era 2 than in era 1 (Figure 2B). Splenectomy was not performed in era 2 because of the larger graft and preoperative portal inflow modulation by splenic arterial embolization. The total bilirubin level on postoperative day 14 was significantly lower in era 2 (1.2 mg/dl) than that in era 1 (3.1 mg/dl, p = 0.013). The frequency of bile duct stricture was lower in era 2 (0%) than in era 1 (25%) but not to a significant degree (p = 0.076). There was no short-term recipient mortality both in eras 1 and 2.

Discussion

The present study shows that our revised donor selection criteria and surgical plan of 2020 through 2022 (era 2) contributed to shortened surgical time and no short-term mortality of recipients or donors after LDLT. With the revised donor selection criteria, right lobe grafts were chosen for all recipients and led to better graft function in the early operative period after LDLT. Moreover, owing to the introduction of the en-bloc sharp division of the arterial biliary bundle at the high-hilar level with the conversion technique for biliary reconstruction, there was no bile duct stricture in era 2.

The key procedure that we introduced in era 2 was the en-bloc sharp division of the arterial biliary bundle at the high-hilar level, which was proposed by Lee, et al in 2004[7] and modified by Soejima, et al in 2008[15]. This procedure has helped preserve the maximum blood supply to the bile duct, resulting in the reduction of biliary anastomotic stricture in recipients[16]. In the present study, this procedure both shortened the operation time of the recipient surgery and prevented bile duct stricture during the follow-up period. Because we performed hilar dissection early in the operation, we could perform liver mobilization under a better surgical field because the liver was devascularized and easily rotat-

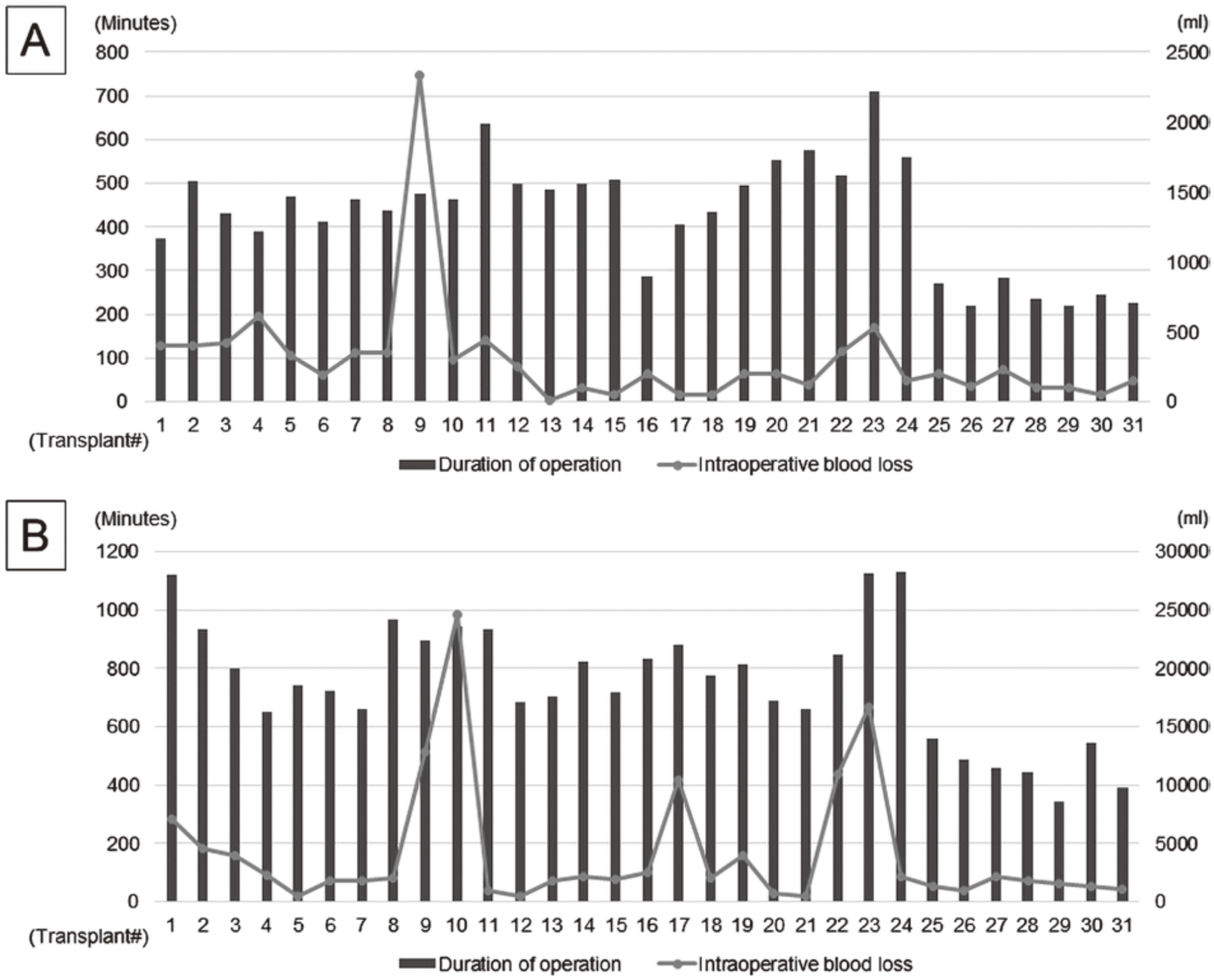

Fig. 2. Operative time and intraoperative blood loss in each transplant for donor (A) and recipient surgery (B).

ed.

Regarding living donor surgery, minimal hilar dissection with the subtraction method has reportedly prevented biliary complications[6]. In addition to this procedure, we introduced a straight line of the parenchymal resection to the IVC under a hanging maneuver and real-time cholangiography for the division of the right hepatic duct. In the present study, these procedures improved surgical results and postoperative outcomes.

In era 2 (2020-2022), we revised our graft selection criteria so that the GRWR was greater than 0.8% and selected right lobe grafts. However, no donors had complications of Clavien-Dindo grade 3 or greater. With larger grafts, short-term graft function was significantly improved, resulting in shorter hospital stays of recipients after LDLTs.

The present study had several limitations. First, this study was retrospective and had a limited number of participants. Another limitation was that this study was performed at a single institution. Our findings need to be validated in independent studies.

In conclusion, our introduced surgical techniques made the surgical procedure of LDLT simple and standardized, resulting in early graft procurement and early total recipient hepatectomy with acceptable outcomes.

Authors have no conflict of interests.

Disclosure : Author contributions by KH and TI developed the main concept and designed the study. KF, MY, RH, MA, YS, SO, and TU were responsible for acquisition of clinicopathological data. KH and TI drafted the manuscript. All authors contributed to editing and critical revision for important intellectual contents.

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