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Original Article

Donor body mass index over 30 is no barrier for pure laparoscopic donor right hepatectomy

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Backgrounds/Aims: Challenges arise when translating pure laparoscopic donor right hepatectomy (PLDRH) results from Asian to Western donors, due to differences in body mass index (BMI). This study compares the outcomes of PLDRH and conventional open donor right hepatectomy (CDRH) in donors with BMI over 30.

Methods: Medical records of live liver donors (BMI > 30) undergoing right hepatectomy (2010–2021) were compared: 25 PLDRH cases vs. 19 CDRH cases. Donor and recipient demographics, operative details, and outcomes were analyzed.

Results: PLDRH and CDRH had similar donor and recipient characteristics. PLDRH had longer liver removal and warm ischemic times, but a shorter post-liver removal duration than CDRH. Donor complication rates were comparable, with the highest complication being grade IIIa in PLDRH, necessitating needle aspiration for biloma on postoperative day 11. Fortunately, this donor fully recovered without additional treatment. No complications exceeding Clavien–Dindo grade IIIa occurred in either group. Recipient outcomes between the groups were similar.

Conclusions: This study supports PLDRH as a viable option for donors with BMI over 30, challenging the notion that high BMI should deter considering PLDRH. The findings provide valuable insights into the safety and feasibility of PLDRH, encouraging further exploration of this technique in diverse donor populations.

Key Words: Living donor; Laparoscopy; Hepatectomy; Body mass index; Safely

INTRODUCTION

Since its first report in 2002 [1], pure laparoscopic donor hepatectomy (PLDH) has gradually developed, with increasing adoption over time. The procedure has expanded from the left lateral section to encompass full left and full right grafts [2-4]. Aligned with this progress, international consensus guidelines have been updated [5-8]. The latest guideline acknowledged PLDH as a standard practice for the left lateral section graft [8]. However, further studies are essential to validate its application for full left and full right grafts.

Recently, Asian centers, particularly Korean ones, including ours, have published several studies showcasing the feasibility and safety of pure laparoscopic donor right hepatectomy (PLDRH) [9-16]. However, translating these study results directly to Western donors presents several challenges, with one of the main reasons being the disparities in body mass index (BMI) between Asian and Western countries. According to the Korean organ transplantation registry study, live liver donors providing full left lobe grafts had a higher BMI, compared to donors contributing to full right lobe grafts; the mean BMI for the latter group was 23.1 kg/m^2 [17]. Additionally, a multicenter study in Korea, specifically focusing on PLDRH, reported a mean donor BMI of 23.4 kg/m^2 [16]. In contrast, recent data from a US center indicated a higher median donor BMI of 26.2 kg/m^2 for living donor liver transplantation (LDLT) [18]. The OPTN/SRTR 2021 annual data report also highlighted that over 15% of live liver donors in the US had a BMI exceeding 30 kg/m^2 [19].

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Several studies have investigated the outcomes of liver donors with a BMI over 30, but the results have been contradictory, indicating that high BMI does not always lead to hepatic steatosis [20-24]. Notably, there have been instances of successful LDLT utilizing liver grafts from donors with a BMI over 30, following rigorous preoperative assessments [23,24]. In these situations, it is crucial to determine if PLDRH is also a feasible and safe option for donors with a BMI over 30. In our earlier report, we examined the impact of donor BMI over 30 on PLDRH [25]. However, this analysis was limited to just 7 cases of PLDRH where the donor BMI exceeded 30. The objective of this study is to conduct, for donors with BMI over 30 in a larger sample size, a comprehensive comparison between PLDRH, and conventional open donor right hepatectomy (CDRH). This study benefits from accumulated experience with PLDRH, aiming to provide a more robust analysis of the outcomes.

MATERIALS AND METHODS

Patients and data

The medical records of live liver donors with a BMI over 30, who underwent right hepatectomy between 2010 and 2021, along with their recipients, were retrospectively examined. Donors who underwent hepatectomies other than right hepatectomy were excluded. The results were then compared between the PLDRH group and the CDRH group. This study received approval from the institutional review board of Seoul National University Hospital (institutional review board number H-2310-058-1474). Informed consent was exempted by the board, since this research involved a retrospective analysis of prospectively collected data.

Donor evaluation and surgical technique

The live liver donor evaluation process at our center has been thoroughly detailed in prior publications [26,27]. Instead of routine liver biopsies, we have routinely utilized magnetic resonance spectroscopy (MRS) since 2009 to assess fat fraction. Additionally, to evaluate bile duct anatomy, magnetic resonance cholangiopancreatography has replaced intraoperative cholangiography. Liver biopsies were selectively performed for potential donors with a fat fraction surpassing 8%–10% based on MRS results, considering factors such as advanced age, liver function irregularities, and high BMI. In instances where liver biopsy was conducted, macrovesicular steatosis below 10% was considered acceptable. For donors with an MRS fat fraction exceeding 8%–10%, a comprehensive weight-loss program was initiated, taking into consideration both the donor's and recipient's conditions [27]. Following the weight reduction program, MRS was repeated to assess the improvement in steatosis.

Before November 2015, our center exclusively performed CDRH. Following the initiation of the PLDH program in our center [28], PLDRH became the standard approach from March 2016, with the learning curve period ending, and selective PLDH being no longer used in practice [9-11,29]. PLDRH was routinely performed in all cases, except when, after extensive consultations with our medical team, donors and their families chose CDRH. Both CDRH and PLDRH techniques implemented at our center share the same fundamental surgical concepts, including the liver hanging maneuver, demarcation, precise midplane liver transection, and optimal bile duct division [9-11,26,30]. The differences between the two techniques lie solely in the methods and instruments used to achieve these principles. In PLDRH, laparoscopic instruments and an indocyanine green near-infrared fluorescence camera are specifically employed to demarcate the exact midplane of the liver, and identify the optimal point for bile duct division [31,32].

Statistical analysis

The results are presented as the median with interquartile range. Continuous variables between groups were compared using the Mann–Whitney U test. Categorical variables were compared using either the chi-square test or Fisher's exact test, as appropriate. A significance level of $p < 0.05$ was applied for all analyses. All statistical calculations were conducted using SPSS software, version 23 (SPSS Inc.).

RESULTS

With donors having a BMI over 30, there were 19 cases of CDRH, and 25 cases of PLDRH. Demographic and preoperative variables between the two groups were similar (Table 1). However, in the PLDRH group, the liver removal time (181.0 minutes vs. 208.0 minutes, $p = 0.011$) and warm ischemic time (defined as the time from hepatic artery ligation to graft liver removal) (4.0 minutes vs. 15.0 minutes, $p = 0.011$) were significantly longer, while the time after liver removal was shorter (98.0 minutes vs. 74.0 minutes, $p < 0.001$), compared to the CDRH group. Additionally, the delta% values, calculated as the ratio of the difference between peak value and preoperative value to the preoperative value, for total bilirubin (325.0 mg/dL vs. 833.3 mg/dL, $p = 0.007$) and AST (885.0 IU/L vs. 1,194.1 IU/L, $p = 0.026$) were higher in the PLDRH group. Despite these differences, the PLDRH group exhibited a shorter hospital stay, compared to the CDRH group (8.0 days vs. 7.0 days, $p = 0.020$), and the rates of donor complications were similar between the two groups. In the CDRH group, there were two cases of grade I complications, one involving ileus, and the other, a wound problem. Additionally, one donor experienced a grade II complication due to venous thromboembolism, which was managed with temporary oral warfarin medication. This donor made a complete recovery, without further issues. In the PLDRH group, there was one case of grade I complication related to a wound problem, and two cases of grade II complications. One donor faced venous thromboembolism and was treated with temporary direct oral anticoagulant,

Table 1. Donor demographics, preoperative variables, and operative outcomes

	Open (n = 19)	Pure laparoscopic (n = 25)	*p*-value
Demographics			
Sex, male:female	11:8	20:5	0.111
Age (yr)	30.0 (23.5–44.0)	29.0 (24.0–39.0)	0.738
Relationship			0.058
Son/daughter	10	21	
Father/mother	0	1	
Brother/sister	4	1	
Husband/wife	3	2	
Others	2	0	
BMI (kg/m^2)	31.8 (30.9–32.3)	31.4 (30.3–32.5)	0.526
ABO incompatibility	1 (5.3)	7 (28.0)	0.111
Preoperative variables			
Estimated remnant liver volume (%)	34.6 (33.7–37.6)	34.6 (32.2–37.4)	0.553
Estimated right graft volume	535.0 (469.0–615.0)	541.0 (475.0–625.0)	0.810
Estimated GRWR	1.5 (1.2–1.6)	1.5 (1.4–1.6)	0.883
Expected number of openings from preoperative image			
Hepatic artery			> 0.999
1	19 (100)	24 (96.0)	
2	0 (0)	1 (4.0)	
Portal vein			> 0.999
1	17 (89.5)	23 (92.0)	
2	2 (10.5)	2 (8.0)	
Bile duct			0.148
1	17 (89.5)	17 (68.0)	
2	2 (10.5)	8 (32.0)	
Operative outcomes			
Macrovesicular fatty change (%)	3.0 (1.0–5.0)	2.0 (1.0–5.0)	0.567
Operative time (min)	295.0 (252.5–307.5)	288.0 (270.0–325.0)	0.810
Liver removal time (min)	181.0 (161.0–203.0)	208.0 (188.0–239.0)	0.011
Time after liver removal (min)	98.0 (89.0–114.0)	74.0 (71.0–84.0)	< 0.001
Warm ischemic time (min)	4.0 (3.0–6.0)	15.0 (10.0–18.0)	0.011
Intraoperative transfusion	0 (0)	0 (0)	NS
Graft weight (g)	888.0 (790.0–979.0)	886.5 (780.0–1,030.0)	0.815
Real GRWR	1.3 (1.1–1.5)	1.3 (1.1–1.5)	0.930
Inclusion of middle hepatic vein	1 (5.9)	1 (4.0)	> 0.999
Postoperative blood tests			
Hb			
Lowest (g/dL)	12.0 (10.6–12.8)	12.4 (11.7–13.1)	0.290
Delta%	21.8 (13.3–27.2)	18.9 (15.0–23.6)	0.483
Total bilirubin (mg/dL)			
Peak	2.2 (1.6–3.7)	3.1 (2.5–4.8)	0.035
Delta%	325.0 (241.7–625.0)	833.3 (533.3–960.0)	0.007
AST (IU/L)			
Peak	176.0 (139.5–237.5)	207.0 (157.0–249.0)	0.209
Delta%	885.0 (846.1–1,203.0)	1,194.1 (900.0–1,487.5)	0.026
ALT (IU/L)			
Peak	153.0 (111.5–226.0)	221.0 (191.0–261.0)	0.009
Delta%	990.9 (629.3–1,440.0)	1,130.8 (944.0–1,503.7)	0.137
Hospital stay (day)	8.0 (7.0–9.0)	7.0 (7.0–8.0)	0.020
Complication			
I	2 (10.5)	1 (4.0)	0.570
II	1 (5.3)	2 (8.0)	> 0.999
IIIa	0 (0)	1 (4.0)	> 0.999
IIIB	0 (0)	0 (0)	NS

Values are presented as median (interquartile range) or number (%).
BMI, body mass index; GRWR, graft to recipient weight ratio; AST, aspartate transaminase; ALT, alanine transaminase; NS, not significant.

Table 2. Recipient demographics and operative outcomes

	Open (n = 19)	Pure laparoscopic (n = 25)	*p*-value
Sex, male:female	15:4	18:7	0.731
Age (yr)	52.0 (45.0–57.0)	58.0 (53.0–63.0)	0.021
BMI (kg/m^2)	24.1 (21.7–26.0)	25.9 (24.0–27.4)	0.046
Etiology			0.473
Hepatitis B virus	11 (57.9)	13 (52.0)	
Hepatitis C virus	1 (5.3)	4 (16.0)	
Alcoholic	5 (26.3)	3 (12.0)	
Others	2 (10.5)	5 (20.0)	
Hepatocellular carcinoma	10 (52.6)	19 (76.0)	0.105
MELD score	14.1 (9.9–17.6)	10.1 (8.2–14.4)	0.089
Hospital stay (day)	16.0 (12.5–22.5)	13.0 (12.0–18.0)	0.318
Complication			
Early major complication[a]	6 (31.6)	5 (20.0)	0.489
Intraabdominal bleeding[b]	1 (5.3)	1 (4.0)	> 0.999
Intraabdominal fluid collection[b]	1 (5.3)	0 (0)	0.432
Wound problem[b]	2 (10.5)	0 (0)	0.181
Portal vein problem[b]	1 (5.3)	0 (0)	0.432
Biliary problem[b]	1 (5.3)	3 (12.0)	0.622
Cardiac problem[b]	1 (5.3)	0 (0)	0.432
Neurologic problem[b]	0 (0)	1 (4.0)	> 0.999
Umbilical vein thrombosis[b]	1 (5.3)	0 (0)	0.432
Common femoral artery pseudoaneurysm[b]	0 (0)	1 (4.0)	> 0.999
Late major complication[a]	5 (26.3)	5 (20.8)	0.728
Intraabdominal bleeding[b]	0 (0)	1 (4.2)	> 0.999
Intraabdominal fluid collection[b]	2 (10.5)	0 (0)	0.189
Portal vein problem[b]	0 (0)	1 (4.2)	> 0.999
Hepatic vein problem[b]	0 (0)	1 (4.2)	> 0.999
Biliary problem[b]	2 (10.5)	3 (12.5)	> 0.999
Diaphragmatic hernia[b]	1 (5.3)	0 (0)	0.432
IVC stenosis[b]	0 (0)	1 (4.2)	> 0.999

Values are presented as median (interquartile range) or number (%).
BMI, body mass index; MELD, model for end-stage liver disease; IVC, inferior vena cava.
[a]Number of recipients who had complications.
[b]Cases of complications.

while another donor experienced grade II ileus. Furthermore, one donor in the PLDRH group had a grade III complication, necessitating needle aspiration for biloma on postoperative day 11. Fortunately, this donor also fully recovered without requiring additional treatment. Notably, no complications exceeding Clavien–Dindo grade IIIa occurred in either group.

On the recipient side, individuals in the PLDRH group were older (52.0 years vs. 58.0 years, $p = 0.021$) and had a higher BMI (24.1 kg/m^2 vs. 25.9 kg/m^2, $p = 0.046$), compared to those in the CDRH group (Table 2). However, the length of hospital stay and the rates of both early and late complications exceeding Clavien–Dindo grade II were similar between the two groups. There was no difference in overall survival between the two groups (Fig. 1), and none of the cases necessitated retransplantation.

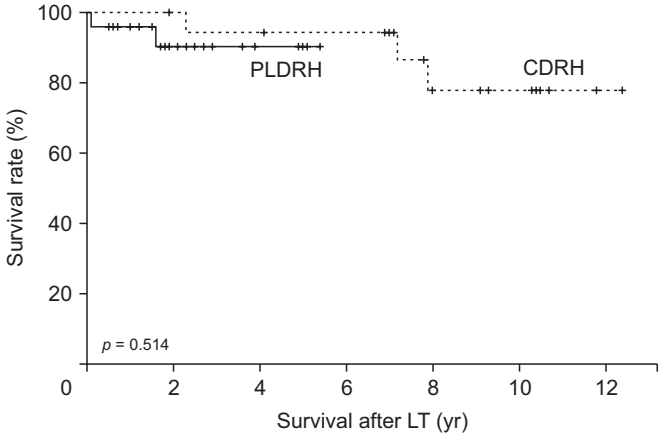

Fig. 1. Kaplan–Meier analysis of overall survival. PLDRH, pure laparoscopic donor right hepatectomy; CDRH, conventional open donor right hepatectomy; LT, liver transplantation.

DISCUSSION

According to our findings, the annual count of live liver donors with a BMI over 30 undergoing right hepatectomy ranged (1 to 7). Between 2010 and 2013, there were (1 to 4) cases, but in the most recent three years (2018 to 2021), this number increased to (5 to 7) cases per year. Although the rise in numbers could potentially introduce a time bias, given that most cases in CDRH occurred between 2010 and 2015, whereas PLDRH cases were performed after 2015, the trend indicates that performing LDLT using a right liver graft from a donor with a BMI over 30 may not adversely affect outcomes for both the donor and recipient. Between 2010 and 2015, our center exclusively performed CDRH procedures, except for one case in 2018, and another in 2020. These exceptions arose because the donors and their families chose CDRH, despite our center's introduction of PLDRH without specific selection criteria during that period. One instance involved a 21-year-old son with a BMI of 31.3 who opted for PLDRH, with an estimated graft volume of 983 mL, and no anticipated vascular or bile duct anatomical variations. The second donor was a 50-year-old wife with a BMI of 31.3. The estimated graft volume was 682 mL, and it was anticipated that there would be multiple bile duct openings. During the bench surgery, it was confirmed that there were three bile duct openings in the graft. Our center did not enforce absolute contraindications for PLDRH, encompassing vascular and bile anatomical variations, as well as graft volume concerns [11,31,33]. Nevertheless, our approach involved thorough discussions with donors and their families concerning the choice of surgical method. We emphasized the innovative nature of PLDRH, while cautioning about its potential for a higher complication rate in the recipient [10,11]. These discussions, influenced by factors such as the larger graft volume in the first case and the donor's advanced age and bile duct variation in the second case, likely played a significant role in the donors' decisions.

When assessing complications resulting from surgery, the donor, distinct from a typical patient, requires special consideration. It is crucial to highlight that only one case reached grade IIIa, necessitating needle aspiration, and no donor in either group experienced complications exceeding this level. In both the CDRH and PLDRH groups, three donors each encountered grade I or II complications, including issues like wound problems, ileus, and venous thromboembolism. These complications align with findings from previous studies on surgeries involving obese patients [22,34]. Surgeons must remain vigilant, especially with donors having a BMI over 30, as they are at risk for these specific complications. Quick suspicion and timely diagnosis are paramount, emphasizing the need for immediate attention. Importantly, since there were no significant differences in donor complications between CDRH and PLDRH [22], these specific complications apply to all live liver donors with a BMI over 30, regardless of the surgical technique chosen, and are not specifically associated with PLDRH, in comparison to CDRH.

Venous thromboembolism, encompassing deep vein thrombosis and pulmonary embolism, is typically associated with prolonged immobilization, a significant risk factor [35]. Despite concerns about the impact of longer operation times on venous thromboembolism, our study revealed similar total operating times between CDRH and PLDRH. Although the liver removal process took longer in PLDRH, the post-liver removal duration was shorter, resulting in comparable overall operating times between PLDRH and CDRH. Interestingly, our previous research, which did not focus on BMI, showed significantly longer operation times in PLDRH, compared to CDRH. This study's finding of similar operative times between PLDRH and CDRH can be attributed to the notably shorter duration after liver removal in PLDRH for donors with a BMI over 30. This difference is primarily due to the smaller incision in PLDRH, compared to CDRH. The additional time required until liver removal is offset by the shorter duration needed to close the abdomen after liver removal in PLDRH, compared to CDRH.

Donor hepatectomy involves obtaining a partial liver graft for a recipient, and the surgical technique employed can impact the quality of the graft. While assessing the donor's outcome is paramount, evaluating the recipient's outcome is also crucial to thoroughly assess the feasibility and safety of the surgical technique, specifically PLDRH in this study. According to the current study findings, rates of both early and late complications and recipient survival were comparable between PLDRH and CDRH. This suggests that PLDRH does not compromise the quality of the liver graft or adversely affect the recipient. In our previous study, which compared 198 cases of CDRH and PLDRH after propensity score matching, we noted a potential higher rate of recipient biliary complications in PLDRH, compared to CDRH [10]. This implies that the rate of recipient biliary complications might be higher in PLDRH for donors with a BMI over 30, considering that a high donor BMI could make the pure laparoscopic technique more challenging in optimally dividing the bile duct. Although not reaching statistical significance, the present study observed a higher rate of multiple expected bile duct openings in PLDRH, compared with CDRH. However, the rate of biliary complications in the recipient remained similar between the two groups.

While discussing the findings of our study, it is essential to recognize that the donors included exhibited no significant liver steatosis. The scope is not all potential donors with a BMI over 30, but specifically those who have already successfully donated their livers. Candidates with a BMI over 30, showing a continuous MRS fat fraction above 8%–10% or liver biopsy indicating more than 10% macrovesicular steatosis, were excluded, and thus did not proceed with liver donation, and are not represented in this study.

This study does have its limitations. Firstly, it is crucial to acknowledge that our research was retrospective in nature,

potentially leading to the underreporting of complications. We relied on the completeness of medical records for our analysis. Secondly, the study was conducted in a single center, meaning the findings might not be readily applicable to other medical facilities. Thirdly, there could be a time bias, given that the PLDRH group is more recent, compared to the CDRH group. A further limitation is the absence of a comparison with PLDRH in donors with a BMI less than 30 in this study. However, it is important to note that our study represents a significant advancement in the field, being the largest investigation to date on PLDRH in donors with a BMI over 30. While our results may not be universally generalizable to all medical centers, they do provide valuable insights. Considering the innovative nature of this technique and its increasing adoption, our findings serve as a pioneering effort, offering important clues about the feasibility and safety of PLDRH, even in donors with a BMI of 30 or higher.

In conclusion, our study suggests that for donors with a BMI over 30, PLDRH can indeed be a viable option. It underscores that a BMI over 30 alone should not deter considering PLDRH as a potential surgical approach.

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CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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Conceptualization: SKH. Data curation: All authors. Methodology: SKH. Writing - original draft: SKH. Writing - review & editing: All authors.

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