Original Article

Impact of pure laparoscopic surgery on bile duct division of living donor left lateral section procurement

Hai-Ming Zhang[1,2,3#], Lin Wei[1,2,3#], Hong-Yu Li[1,2,3], Li-Ying Sun[1,2,3], Wei Qu[1,2,3], Zhi-Gui Zeng[1,2,3], Ying Liu[1,2,3], Zhi-Jun Zhu[1,2,3]

[1]Beijing Friendship Hospital, Capital Medical University, Beijing, China; [2]Clinical Center for Pediatric Liver Transplantation, Capital Medical University, Beijing, China; [3]National Clinical Research Center for Digestive Diseases, Beijing, China

Contributions: (I) Conception and design: ZJ Zhu, HM Zhang, L Wei; (II) Administrative support: ZJ Zhu; (III) Provision of study materials or patients: L Wei, HY Li, LY Sun, W Qu, ZG Zeng, Y Liu; (IV) Collection and assembly of data: HM Zhang; (V) Data analysis and interpretation: HM Zhang, L Wei; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

[#]These authors contributed equally to this work and should be considered as co-first authors.

Correspondence to: Zhi-Jun Zhu. Liver Transplantation Center, Beijing Friendship Hospital, Capital Medical University, Beijing 100050, China. Email: zhu-zhijun@outlook.com.

Background: Although laparoscopic living donor left lateral section liver procurements represents an established and safe procedure, there remains much discussion on this topic. In particular, the issue of whether laparoscopic living donor liver procurement increases the difficulty of the surgery and potential complications for recipients continue to confound experts in this field.

Methods: In this report, data from 180 cases of living donor left lateral section liver transplantation patients were analyzed retrospectively. Of these 180 cases, 106 grafts were procured by open surgery and 74 by pure laparoscopic surgery.

Results: While surgery durations and blood loss were decreased in donors from the laparoscopic surgery group, increased biliary openings of grafts and relatively high peak aspartate aminotransferase (AST) levels were present in both donors and recipients with this procedure.

Conclusions: Laparoscopic living donor left lateral section liver procurement represents a safe and effective procedure for both donors and recipients. However, laparoscopic surgery can more frequently lead to multiple biliary tracts in the graft and its impact on the prognosis of recipients remains uncertain. Use of routine X-ray based intraoperative cholangiography may help to reduce this problem.

Keywords: Pure laparoscopic surgery; living donor liver transplantation (LDLT); biliary complication; prognosis

Submitted Oct 09, 2021. Accepted for publication Feb 10, 2022. Published online Jul 07, 2022.
doi: 10.21037/hbsn-21-418
View this article at: https://dx.doi.org/10.21037/hbsn-21-418

Introduction

Due to a shortage of liver grafts from deceased donors, many liver transplant recipients cannot receive liver transplants in a timely manner according to their needs. The relatively lower willingness of Asians to donate, has resulted in the rapid development of living donor liver transplantation (LDLT) as an alternative procedure. In pediatric liver transplantations, recipients are more likely to accept left lateral liver grafts from their parents. According to the "data report of liver transplantation in China 2018", pediatric LDLT accounted for 71.92% of pediatric liver transplantations performed in mainland China in 2018. The overall three-year recipient survivals of these pediatric living donor liver transplantations was 92.54%.

Conventional living donation requires a relatively elongated abdominal incision as part of the surgical procedure. The consequent effects on pain, gastrointestinal function and appearance all contribute to the hesitancy experienced by potential donors. In contrast, the minimally invasive living donor liver procurement has stimulated the development of LDLT. The first laparoscopic liver surgery was conducted in 1993 (1). In 2008, The Louisville Statement recommended use of a left lateral sectionectomy (2) with the benefits of this procedure being supported by data from observational studies and randomized clinical trials (3).

A gradual development of laparoscopic left lateral section liver procurements in LDLT has resulted since its first report in 2002 (4-6). However, liver transplantation remains one of the most complicated abdominal surgeries. For example, vascular and biliary anastomoses exert increased levels of potential difficulties encountered with donor liver procurements, and graft volume, number and length of vessels and bile duct stump all need to be precisely controlled in these transplants. Therefore, the reliability of laparoscopic living donor liver procurement as an alternative procedure has attracted considerable attention and study. The safety of laparoscopic left lateral section (LLLS) liver procurement in living donors has been established with the consensus of most experts in the field as based on a review of this procedure over the period from 2015 to 2018 (7-9). The advantages of LLLS liver procurement have been reported (10,11) and no statistically significant differences in donor prognosis have been observed between laparoscopic and open surgery. These findings have served as the basis for use of laparoscopic living donor liver procurements (12). However, the potential impact of laparoscopic surgery on the recipient also warrants consideration as it represents the absolute basis for judging the therapeutic effect of liver transplantation. Although there exist some consensuses regarding outcomes of donors and patients, the impact of laparoscopic surgery on the recipient has yet to be described in detail. Several reports involving a laparoscopic right lobe procurement have indicated an unsatisfactory outcome of the biliary division of laparoscopic surgery (10,11). As donors with complicated biliary variation represent some candidates for open surgery (13), the slight increase in the recipient's biliary stricture after laparoscopic LLLS procurement as reported in the literature (14,15) may indicate a significant source of factors which cannot be ignored. That is, the potential existence of a "Hidden Reef" may be associated with promoting laparoscopic living donor liver procurement, especially for LLLS. In this way, the positive aspects experienced may be diminished under circumstances that could be considered as exposing the recipient to an increased degree of discomfort or risk.

Given this varied background information, in this study we attempt to clarify the impact of laparoscopic surgery on bile duct cleavage. To accomplish this goal, we analyzed the data of donors and recipients of LDLT as performed in the Beijing Friendship Hospital of Capital Medical University. In specific, a detailed data analysis was conducted by matching or correcting for the influence of potential confounding factors such as biliary anatomy, donor body height and PELD scores. We present this article in accordance with the STROBE reporting checklist (available at https://hbsn.amegroups.com/article/view/10.21037/hbsn-21-418/rc).

Methods

The present study was performed in accordance with the Declaration of Helsinki (as revised in 2013). The ethics committee of the Beijing Friendship Hospital of Capital Medical University approved this retrospective study (2020-P2-181-01). Inform consent was waived due to the retrospective nature of this study. All donors underwent left lateral lobe donation. With the exception of those involving reduced left lateral lobe transplantation and auxiliary liver transplantation, the corresponding recipients accepted the LDLT over the period from January 1, 2018 to January 31, 2021. No laparoscopic hand-assisted living donor hepatectomy was performed and there was no age limit in the design of this study. However, only children were enrolled, with most being <3 years of age. The cases reviewed were allocated into either a conventional open surgery group or pure laparoscopic surgery group.

Evaluation and operation

All donors received a comprehensive disease screening and anatomical evaluation. Liver dynamic computed tomography (CT) and magnetic resonance cholangiopancreatography (MRCP) were used to visualized blood vessels and bile ducts. CT volumetry with use of an IQQA®-3D liver system was also performed. When imaging suggested a possible parenchymal abnormality in the donor's liver (e.g., steatosis), a liver biopsy was executed to determine the feasibility of donation. Following requirements of the Chinese and Beijing governments, each living liver donation and transplant recipient were provided with independent ethical and administrative approvals.

The surgical procedures were similar to that as described in our former reports (16-18). After dissection of the perihepatic ligament and hilar structure of left lobe, an incision line was marked at 0.5 to 1 cm to the left of the falciform ligament, as determined by connecting a line from the left hepatic vein to the division of the portal vein and bile duct. In our center, the same group of transplant surgeons were responsible for both open and laparoscopic donor liver procurements and a similar incision line was used in the two groups. When the parenchyma of liver was divided, portal vein branches to S4 were severed using a "hem-o-lok". In the process of the laparoscopic left lateral procurement, 1–2 Pringle maneuvers were performed at 10–15 minutes each with an interval of at least 5 minutes. The intravenous real-time ICG fluorescence cholangiography and image of MRCP were used to guide the bile duct cleavage. X-ray based intraoperative cholangiography was not mandatory. Finally, the left hepatic vein was divided and closed with use of a vascular staple cutter. The left portal vein, arteries to the left lobe and left hepatic duct were also severed using a "hem-o-lok". In the open group, the donor bile duct stump was sutured and closed, while in the laparoscopy group, it was clamped with use of a clip (Hem-o-lok).

Study end points and definitions

The primary endpoint was the incidence of multiple bile ducts, including multiple openings after graft procurement and multiple anastomoses of bile ducts during implantation. Clavien-Dindo III–V complications of the donor, Clavien-Dindo III–V surgical complications of the recipient along with 90-day and 1-year cumulative graft survivals were secondary endpoints. Surgical complications were defined as those resulting from surgical procedures or those requiring surgical management. Rejections and cardiopulmonary diseases of the recipients were not included in the analyses of this study. Postoperative laboratory tests, including alanine aminotransferase (ALT), aspartate aminotransferase (AST), total bilirubin (TBIL) of donors and ALT, AST and international normalized ratio (INR) of recipients were also included as secondary observational indices.

The impact of donor anatomical variations in the bile duct was quantified as achieved by measuring the length of the left hepatic duct eligible for division in the preoperative MRCP. The length of the potential cutting area of the left hepatic duct was measured as starting from the leftmost branch to the right lobe and the rightmost branch to the left lateral lobe. When no single left hepatic duct could be selected as the point of incision, the length of the potential cutting area was defined as a negative number, and the value used was that of the distance between the origins of the main hepatic ducts of the left lateral section (Figure S1).

PELD scores were recalculated from laboratory results just prior to transplantation. The PELD Score = 0.480 × Ln (bilirubin mg/dL) + 1.857 × Ln (INR) − 0.687 × Ln (albumin g/dL) + 0.436 (for patients transplanted before the patient's first birthday) and + 0.667 (if the patient experienced a growth failure) (<−2 standard deviation). No exceptional score was added as based on any diagnosis. Laboratory values <1.0 were assigned a score of 1.0 for the purposes of PELD score calculations.

Statistical analysis

Data showing a normal distribution were presented as "means ± SDs" and were compared with use of *t* or *t*' tests. Data failing to show a normal distribution were presented as "medians and ranges" and were compared with use of the Mann-Whitney U-test. ALT and AST levels were subjected to a logarithmic transformation to generate a normal distribution prior to analysis of interaction effects as performed with use of a repeated measures analysis of variance (RM ANOVA). Post-hoc analyses as conducted for each post-surgical period were analyzed with use of the Mann-Whitney U-test. Survival curves were drawn using the Kaplan-Meier method and differences between curves were compared with use of the log-rank way. Binary logistic regression models were established to identify and adjust the impact of laparoscopic surgery and other risk factors on multiple bile ducts. ROC curves were used to illustrate the predictive ability of logistic regression models. Finally, a propensity-matched sample for sensitivity analysis was also generated.

Results

Baseline characteristics of donors and recipients

A total of 180 LDLT cases involving the left lateral section were included in this study. The median follow-up time was 645.5 days (range: 7–1,205 days), while all donors and surviving recipients were followed for >90 days. Among these cases, one patient underwent liver retransplantation, with this patient receiving left lateral lobes from his mother in the primary transplantation and father for the retransplantation. These two episodes of transplantation were analyzed as two separate cases. Baseline characteristics of donors and recipients are summarized in *Table 1*. There were 106 cases of living donation by open surgery and 74 by laparoscopic surgery. Baseline characteristics of age,

Table 1 Baseline characteristics of donors and recipients

Characteristics	Open	Laparoscopic	P
n	106	74	
Age of recipient (years), median, range	1.00, 0.33–10.83	0.83, 0.25–8.33	0.205
Gender of recipient, n (%)			0.816
Male	54 (50.94)	39 (52.70)	
Female	52 (49.06)	35 (47.30)	
Blood group of recipient, n (%)			0.223
A	30 (28.30)	25 (33.78)	
AB	12 (11.32)	4 (5.41)	
B	32 (30.19)	16 (21.62)	
O	32 (30.19)	29 (39.19)	
Height of recipient (cm), mean ± SD	79.17±20.19	74.79±16.36	0.202
Weight of recipient (kg), median, range	8.65, 5.00–36.00	8.15, 4.50–26.00	0.294
PELD score of recipient[a], median, range	5.99, −9.83–60.57	12.04, −10.63–51.55	0.043
Diagnosis, n (%)			0.421
Acute hepatic failure	2 (1.89)	1 (1.35)	
Cholestasis disease	79 (74.53)	56 (75.68)	
Cirrhosis/portal hypertension	3 (2.83)	1 (1.35)	
Glycogen storage disease	2 (1.89)	0 (0.00)	
Hereditary hemorrhagic telangiectasia	0 (0.00)	1 (1.35)	
MSUD	2 (1.89)	0 (0.00)	
Organic acidemia	5 (4.72)	4 (5.41)	
Retransplantation	0 (0.00)	1 (1.35)	
Tyrosinemia	1 (0.94)	2 (2.70)	
Urea cycle disorder	12 (11.32)	8 (10.81)	
Age of donor (years), mean ± SD	32.31±4.83	33.15±6.17	0.357
Gender of donor, n (%)			0.555
Male	52 (49.06)	33 (44.59)	
Female	54 (50.94)	41 (55.41)	
Height of donor (cm), mean ± SD	166.96±8.21	167.83±7.71	0.478
Weight of donor (kg), mean ± SD	63.99±10.52	64.81±10.61	0.614
BMI of donor (kg/m^2), mean ± SD	22.83±3.07	22.97±3.15	0.765
Blood group of donor, n (%)			0.658
A	26 (24.53)	24 (32.43)	
AB	7 (6.60)	4 (5.41)	
B	30 (28.30)	21 (28.38)	
O	43 (40.57)	25 (33.78)	

Table 1 (*continued*)

Table 1 (*continued*)

Characteristics	Open	Laparoscopic	P
ABO blood group compatibly, n (%)			0.572
Compatible	92 (86.79)	62 (83.78)	
Incompatible	14 (13.21)	12 (16.22)	

[a], PELD Score = 0.480 × Ln (bilirubin mg/dL) + 1.857 × Ln (INR)-0.687 × Ln (albumin g/dL) + 0.436 (scores for patients transplanted before the patient's first birthday) + 0.667 (if the patient has growth failure, <−2 standard deviation); no exceptional score was added according to any diagnosis. SD, stable disease; PELD, pediatric end-stage liver disease; MUSD, maple syrup urine disease; INR, international normalized ratio.

Table 2 Intraoperative indexes of donors and recipients

Indexes	Open	Laparoscopic	P
Cold ischemia time (h)	1.43, 0.33–4.43	0.88, 0.35–3.22	0.642
Operation time of recipient (h)	6.71±1.73	6.34±1.70	0.456
Blood loss of recipient (mL)	120, 30–400	150, 30–800	0.028
Operation time of donor (h)	4.19±1.30	3.30±1.06	<0.001
Blood loss of donor (mL)	150, 5–800	50, 20–800	<0.001
Left lateral graft weight (g)	250.09±65.38	260.32±53.64	0.298
GRWR (%)	2.64, 0.96–6.00	2.87, 1.20–5.28	0.023
Left hepatic duct eligible for division (cm)	1.20, −1–2.83	1.21, −0.5–2.97	0.921
Number of hepatic artery anastomosed			0.541
1	67	45	
2	38	29	
3	1	0	
Number of biliary duct anastomosed			<0.001
1	95	47	
2	9	26	
3	2	1	

Dada are presented as means ± SD or median, range. GRWR, graft, and recipient weight ratio.

gender, blood group, height and weight for both donors and recipients were similar between the two groups. There were no differences in the diagnosis of recipients and BMI of donors. The proportion of ABO-incompatible LDLTs was also quite similar between the groups. PELD scores of recipients in the laparoscopic surgery group were greater than those in the open surgery group.

Intraoperative indices

Among all intraoperative indices recorded, blood loss of donors and duration of surgery were reduced in the laparoscopic surgery group. At the same time, blood loss within the recipient, graft, and recipient weight ratio (GRWR), and number of biliary ducts of the graft were all increased in the laparoscopic surgery group (*Table 2*). Cold ischemia times, surgery duration for the recipient, graft weight, number of hepatic arteries anastomosed, and length of left hepatic duct eligible for division were similar in both groups.

Postoperative laboratory data

As AST levels within recipients were repeatedly measured,

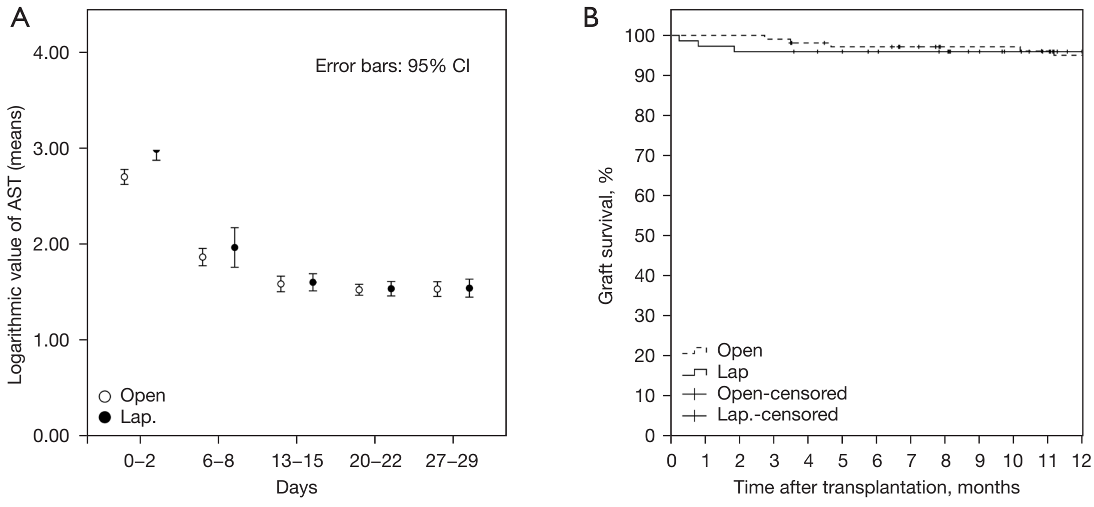

Figure 1 Outcome of grafts. (A) Mean logarithmic AST values in recipients. (B) Graft survivals in the open and laparoscopic surgery groups. CI, confidence interval; AST, aspartate aminotransferase.

Table 3 Average laboratory indexes of recipients and donors

Indexes	Open	Laparoscopic	P
Average level of recipient's laboratory indexes (0–2 days)			
AST (IU/L)	444.80, 63.40–2,764.77	766.52, 167.70–3,832.13	<0.001
ALT (IU/L)	465.50, 97.00–3,443.00	756.50, 257.00–3,276.00	<0.001
INR	1.48, 1.07–2.96	2.04, 1.06–3.52	<0.001
Average level of donor's laboratory indexes (0–2 days)			
AST (IU/L)	157.70, 35.80–585.00	200.50, 68.00–987.87	0.039
ALT (IU/L)	214.50, 69.50–819.00	292.00, 56.67–1,329.33	0.018
TBIL (μmol/L)	27.11, 10.25–71.70	21.85, 10.09–78.19	0.014

Dada are presented as median, range. AST, aspartate aminotransferase; ALT, alanine aminotransferase; INR, international normalized ratio; TBIL, total bilirubin.

postoperative determinations of these recipients were assessed at multiple periods: 0–2, 6–8, 13–15, 20–22, and 27–29 days. The average AST value for each period was calculated and compared. A significant group * time interaction was obtained as indicated with the RM ANOVA (*Figure 1A*, P=0.003). Post-hoc analyses revealed that a significant difference in AST levels within the recipients (P<0.001) was only present at 0–2 days after transplantation (*Table 3*). Levels of ALT and INR within recipients at this time period were also found to exhibit statistically significant differences between the laparoscopic and open groups (P<0.001 and P<0.001, for both).

The average levels of AST, ALT and TBIL from donors were compared between groups in the first and second observation periods (0–2 and 6–8 days). While AST (*Table 3*), ALT and TBIL levels of donors in the laparoscopic group were significantly greater than those in the open group at 0–2 days, no significant differences were present at 6–8 days. Therefore, within this initial 0–2 days post-surgery, AST, ALT and INR levels of recipients and AST, ALT and bilirubin levels of donors in the laparoscopic group were increased as compared with that observed in the open surgery group, differences which dissipated within one week.

Table 4 Surgical complications and survival of donors and recipients

Complications	Open	Laparoscopic	P
Recipient surgical complications (Clavien-Dindo grade III–IV)			0.365
No	90 (84.91%)	59 (79.73%)	
Yes	16 (15.09%)	15 (20.27%)	
Intestinal perforation	3	2	
Intestinal obstruction	1	0	
Biliary stricture	3	1	
Bile leakage	3	5	
Intraperitoneal hemorrhage	1	1	
Chylous leakage	0	1	
Hepatic artery thrombosis	0	2	
Portal vein thrombosis/stricture	3	1	
Pleural effusion/intraperitoneal effusion	2	2	
90 days cumulative graft survival	99.1%	95.9%	0.161
1 year cumulative graft survival	95.0%	95.9%	0.896
1 year cumulative recipient survival	95.0%	95.9%	0.901
Donor surgical complications (Clavien-Dindo grade III–IV)			0.686
No	99 (93.40%)	71 (95.95%)	
Yes	7 (6.60%)	3 (40.54%)	
Bile leakage	6	1	
Biliary stricture	0	1	
Bile leakage and incisional hernia	1	0	
Intraperitoneal effusion	0	1	
Length of donor ICU stay (days)	1, 0–2	1, 0–2	0.883
Length of donor hospital stay (days)	7, 5–12	7, 5–10	0.903
1 year cumulative donor survival	100%	100%	1

Complications and outcomes

A summary of the outcomes of donors and recipients are contained in *Table 4*. There were no statistically significant differences in surgically-related complications between the two groups. The 90 day and 1-year survival rates of grafts (*Figure 1B*) were similar, as were 1-year survival rates of donors and recipients. Of all the complications assessed, rejection and cardiopulmonary problems were not included. As ICU stays of recipients could be affected by an array of medical factors (e.g., hepatopulmonary syndrome), this variable was not analyzed. Among surgical complications, intestinal perforation was more likely to be a result of infection. Although more cases of bile leakage were observed in the laparoscopic group, this condition failed to achieve statistical significance.

There were six deaths within one year after transplantation, including one death after retransplantation due to biliary stricture (*Table 5*), which comprised the only problem potentially associated with surgical procedures.

Factors associated with multiple biliary openings in graft

Logistic regression models were employed to further clarify

Table 5 Causes of death in recipients

Causes	Open	Laparoscopic	Time of onset (POD)
Cause of death			
Acute rejection and infection following rejection therapy	1		24
Pulmonary infection and myocarditis	1		142
Preoperative cerebral edema did not relieve	1		0
Infection after the second operation for biliary anastomotic stenosis		1	83
Cardiogenic shock, electrolyte disturbance		1	7
Upper gastrointestinal hemorrhage		1	340
Cause of retransplantation			
Late onset biliary stricture and cholestatic cirrhosis	1		119

POD, post operation day.

Table 6 Factors associated with multiple biliary openings

Factors	Univariate analysis		Multivariate analysis 1[a]	
	P	OR (95% CI)	P	OR (95% CI)
Age of recipient (year)	0.108	0.831, 0.663–1.042		
Height of recipient (cm)	0.207	0.986, 0.964–1.008		
Weight of recipient (kg)	0.416	0.970, 0.900–1.044		
Left lateral graft weight (g)	0.908	1.000, 0.993–1.006		
LAP. *vs.* OPEN	0.000[b]	4.961, 2.267–10.860	<0.001[c]	8.999, 3.149–25.710
Gender of donor (male *vs.* female)	0.140	1.724, 0.836–3.557		
BMI of donor (kg/m^2)	0.412	1.050, 0.934–1.180		
Age of donor (year)	0.677	1.014, 0.950–1.081		
Number of hepatic artery anastomoses	0.049[b]	2.023, 1.004–4.079	0.355[d]	1.524, 0.625–3.720
Left hepatic duct eligible for division (cm)	0.000[b]	0.266, 0.131–0.540	<0.001[c]	0.203, 0.089–0.463
PELD score of recipient	0.073[b]	1.021, 0.998–1.044	0.214[d]	1.019, 0.989–1.050
Height of donor (cm)	0.017[b]	1.060, 1.011–1.113	0.005[c]	1.096, 1.029–1.168
Weight of donor (kg)	0.048[b]	1.035, 1.000–1.071	0.269[d]	1.030, 0.978–1.085
Operation time of donor (h)	0.984	0.997, 0.753–1.320		
Blood loss of donor (mL)	0.341	1.001, 0.999–1.004		

[a], binary logistic regression analysis (backward LR); [b], factors with P<0.1 in the univariate analysis entered the multivariate analysis; [c], significant value in the final multivariate model by 3 factors: LAP. *vs.* OPEN, common trunk length of left biliary tract and height of donor; [d], significant value in the multivariate model just before this factor was excluded. OR, odds ratio; CI, confidence interval; BMI, body mass index; PELD, pediatric end-stage liver disease.

the impact of laparoscopic surgery on bile duct dissection and determine independent factors associated with multiple biliary openings (*Table 6*). Laparoscopic surgery was an independent risk factor for multiple biliary openings after adjusting for length of the left hepatic duct eligible for division. Interestingly, the height of the donor was also correlated with multiple biliary openings in the final model. As donor's height may be related to the anteroposterior

Table 7 Factors associated with multiple biliary openings in multivariate analysis 2

Factors	Multivariate analysis 2[a]	
	P	OR (95% CI)
Age of recipient (year)	0.002	0.346, 0.178–0.672
Weight of recipient (kg)	0.015	1.341, 1.058–1.7
LAP. *vs.* OPEN	<0.001	10.318, 3.254–32.714
Left hepatic duct eligible for division (cm)	<0.001	0.144, 0.057–0.362
Height of donor (cm)	0.002	1.124, 1.046–1.208

[a], binary logistic regression analysis (enter). OR, odds ratio; CI, confidence interval.

diameter of the liver, a large anteroposterior diameter may compel the surgeon to relocate the incision line to the left to obtain a thinner left lateral section, which increases the risk of multiple bile ducts. The weight and age of recipients were also correlated with the demand for a thinner graft. Therefore, we added these two factors into model and, as expected, the inclusion of these factors slightly increased the predictive power of the model (*Table* 7, Figure S2). In the second model, laparoscopic surgery remained an independent factor after correction for these potential influences.

Sensitivity analysis

As significant baseline differences in the PELD scores were present between the groups, a sensitivity analysis through propensity matching was performed. All baseline factors with between group P values of <0.5 were propensity-matched. After matching these factors, increasing or decreasing trends in the laparoscopic group were reversed, though differences in other factors appeared to be only slightly increased (Table S1). Significant differences in blood loss of recipients, surgery durations of donors, number of biliary ducts anastomosed and average level of recipient's laboratory indices were validated in the matching sample (Table S2). The differences in donor's laboratory data were reduced (Table S3). There were no statistically significant differences between groups for levels of AST (P=0.297), ALT (P=0.109) and TBIL (P=0.067) within the first three days following surgery (Table S3) and no significant differences in outcomes after propensity matching. In the laparoscopic group, there were slight decreases in donor complications and increases in recipient complications. Survivals of graft, donor and recipient in the laparoscopic group were similar to those in the open group (Table S4).

Discussion

A reduced or similar incidence of biliary complications was found in donors with LLLS liver procurements (19,20), but the incidence of biliary complications in their recipients has received relatively little attention in many studies (6,21-24). While not statistically significant, the incidence of biliary stricture in the laparoscopic group recipients was relatively high, as reported in several studies involving laparoscopic left lateral section liver procurements (14,15). It should be noted that small sample sizes and confounding factors, such as biliary tract anatomical variation, may influence the presentation of this problem. In clinical practice, anatomical variations not conducive to biliary cleavage are usually managed by open surgery and with a precise arrangement of anastomoses, biliary complications may be reduced. Thus the limited number of increases in recipient biliary stricture may result from a significant defect of laparoscopic surgery on biliary tract divisions.

It has been reported that multiple bile duct openings in the graft were more frequently found in laparoscopic living donor right lobe liver procurements (10,11), though these increases in biliary tract complications did not always achieve statistical significance (11,25). Surgeons may not be able to determine whether the remaining portion of the donor's bile duct was injured, which would then result in the site of the bile duct division tending to be moved toward the graft side (10,26). During laparoscopic procurement, the "clip and cut" procedure as applied to the bile duct may also reduce the length of the bile duct graft (27), due to the width of the clip. Although there is a relatively long trunk of the left biliary duct, these above issues can also increase the probability for multiple openings of bile ducts in LLLS grafts, which would then increase the difficulty for biliary anastomosis. With regard to describing the impact of laparoscopic surgery in LLLS graft procurement, the number of open bile duct of grafts will provide a more direct and sensitive observational marker than the incidence of biliary complications. In our study, results of the univariate analysis revealed that a significant increase in multiple biliary openings were present in LLLS graft procurements. As based on results obtained with a limited sample size, controlling the influence of biliary tract anatomical feathers will be more helpful in demonstrating the influence of laparoscopic surgery. A wide clip or left shift division point may not affect the left biliary tract with a long single trunk. The results as obtained with the multivariate analysis were, again consistent with our expectations, in that the anatomical characteristics of the biliary tract and laparoscope were independent factors affecting multiple biliary openings. Based on a previous report of LLLS procurements (14) it was found that the frequency of multiple biliary branches, which were >50%, was similar in the laparoscopic and open surgery groups. Such results were likely attributable to more trans-umbilical divisions of the liver in the open surgery group (28). The effect of laparoscopic surgery on biliary tract cleavage in our study may be more pronounced under conditions of classical left lateral section procurements.

In order to reduce potential gallbladder damage (29), X-ray based intraoperative cholangiography was not performed in the laparoscopic surgery of some donors, with only indocyanine green real-time imaging used to divide the biliary tract. Such an approach may be a critical factor in increasing multiple biliary branches in the graft. Although indocyanine green imaging may be useful for intraoperative identification of the biliary tract, it does have limitations (30). Based on the results of this study and our experience, indocyanine green real-time imaging cannot replace X-ray based intraoperative cholangiography, but may best be used only as a supplementary method. Moreover, in parents who serve as donors for young children, the biliary tract is usually not dilated and the capacity for MRCP imaging is also significantly reduced. Now, we have utilized routine X-ray based intraoperative cholangiography to confirm the position of bile duct dissection, and this technique may also improve the influence of laparoscopy on bile duct dissection.

We also found that the height of the donor was independently correlated with multiple biliary openings. A possible explanation for this effect may be that a shift in the cut line to the left in taller donors may reduce the anteroposterior diameter of the graft. This speculation is supported by results obtained with the multivariate model which includes such factors as donor height and recipient age and weight (*Table* 7, Figure S2). When the cut line of the liver was close to the falciform ligament, there is an increased possibility for more accidental traverses of bile duct branches to the left lateral section.

The relatively reduced durations of surgery we found in the laparoscopic surgery group differs from that of other reports (14,20,22). However, the overall times required for surgery have been showing a gradual decrease over the past few years with times of 7 hours 58 minutes ± 1 hour in 2015 (22), 429±60 (20) and 277.9±16.3 (14) minutes in 2018 and 383.0±64.0 minutes in 2021 (15), which are consistent with a learning curve. Similarly, surgical durations for open surgery have shown reductions over these time periods. When comparing laparoscopic versus open surgical procedures, factors such as surgical proficiency and seamless linkage may contribute to differences in surgical durations. In cases with relatively short times of surgery (14), difference in surgical durations between the laparoscopic versus open surgery were no longer present. Surgical times as obtained in our current study were shorter than that of most other reports, and the difference in operation time was reversed. We believe that with acceleration in intra-abdominal procedures differences in surgical durations became less remarkable between the two groups. The advantages of a more rapid entering and closing of the abdominal cavity may be an obvious factor involved with reducing surgical times with laparoscopic surgery. In addition, use of indocyanine green real-time imaging instead of X-ray based intraoperative cholangiography in many laparoscopic surgeries of this study may be another reason for the reduction in surgery times in the laparoscopic group (10).

Based on the results of this study, laparoscopic procedures exert a greater impact on graft injury. When grafts were procured by laparoscopic surgery, the average levels of AST, ALT and INR of recipients in the first three days following surgery were relatively high. At the same time, average levels of AST, ALT and TBIL of donors were also elevated during these early days after laparoscopic surgery. In comparison with open surgery, relatively increased peak AST and ALT levels have also been reported in laparoscopic right lobe procurements (10). While laparoscopic procurement is considered a technique with minimal external exposure, similar internal invasiveness is experienced as that of the open method (10). Alternatively, we believe that a more likely explanation may be that involved with the frequent blocking of hepatic blood flow to control bleeding in laparoscopic surgery. Surgeons may more frequently block the blood inflow of liver in laparoscopic surgery to avoid uncontrolled bleeding, while compression at the bleeding site may be the first procedure employed in open surgery before use of other hemostasis procedures. From the results of this study, we found that blood loss in LLLS procurement was reduced, which was consistent with findings of previous reports. However, this result appears to be the consequence of intentional behavior rather than a technical advantage of laparoscopic surgery. In addition, it should be noted that a median difference of 100 mL of blood loss may have only a minimal clinical impact. Compared with that of the warm and cold ischemia injury that can occur with a cadaveric graft, the injury encountered with living donor liver transplantation is relatively slight and controllable (31). Although laparoscopic surgery may slightly increase the graft injury, it does not appear to significantly change the prognosis of living recipients. In this study, the data obtained on recovery of liver function markers in the period following surgery also provides support for this conclusion. However, in high-risk donors or recipients, the potential for an adverse impact associated with this procedure will require further study.

In this study, we report that survivals of both donors and recipients were similar between the laparoscopic and open surgery groups. A slight increase in surgical complications was observed in the laparoscopic surgery group, especially from bile leakage and hepatic thrombosis. As the sample size was quite limited and there was a low incidence of complications it was not possible to establish any clear differences between the groups. Improvements in the precision and techniques involved with biliary anastomosis may also resolve some of the complications associated with multiple biliary tracts. However, laparoscopic procedures may still exert a potential adverse impact of LLLS grafts on recipients, which remains a concern of biliary stricture in long-term follow-ups.

Conclusions

In summary, our findings are generally consistent with the current consensus of experts in the field that LLLS procurement represents a safe and effective procedure for both donors and recipients. However, laparoscopic surgery may more frequently lead to multiple biliary tracts in the graft and its impact on the surgical procedure and prognosis of the recipient remains uncertain. Routine X-ray based intraoperative cholangiography may help to resolve this issue. As based on our experience, the decrease of blood loss during laparoscopic surgery may result from frequent attempts involved with controlling portal blood flow, which can have a mildly adverse impact on early liver functions of donors and recipients rather than reduce donor injury.

Acknowledgments

Funding: This study was supported by grants from Capital's Funds for Health Improvement and Research (No.2020-1-2024) and Beijing Municipal Science & Technology Commission (No. Z211100002921026).

Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://hbsn.amegroups.com/article/view/10.21037/hbsn-21-418/rc

Data Sharing Statement: Available at https://hbsn.amegroups.com/article/view/10.21037/hbsn-21-418/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://hbsn.amegroups.com/article/view/10.21037/hbsn-21-418/coif). ZJZ serves as an unpaid editorial board member of *Hepatobiliary Surgery and Nutrition*. The other authors have no conflicts of interest to declare.

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 present study was performed in accordance with the Declaration of Helsinki (as revised in 2013). The ethics committee of the Beijing Friendship Hospital of Capital Medical University, approved this retrospective study (2020-P2-181-01). Inform consent was waived due to the retrospective nature of this study.

References

1. Azagra JS, Goergen M, Gilbart E, et al. Laparoscopic anatomical (hepatic) left lateral segmentectomy-technical aspects. Surg Endosc 1996;10:758-61.
2. Buell JF, Cherqui D, Geller DA, et al. The international position on laparoscopic liver surgery: The Louisville Statement, 2008. Ann Surg 2009;250:825-30.
3. Macacari RL, Coelho FF, Bernardo WM, et al. Laparoscopic vs. open left lateral sectionectomy: An update meta-analysis of randomized and non-randomized controlled trials. Int J Surg 2019;61:1-10.
4. Cherqui D, Soubrane O, Husson E, et al. Laparoscopic living donor hepatectomy for liver transplantation in children. Lancet 2002;359:392-6.
5. Soubrane O, Cherqui D, Scatton O, et al. Laparoscopic left lateral sectionectomy in living donors: safety and reproducibility of the technique in a single center. Ann Surg 2006;244:815-20.
6. Kim KH, Jung DH, Park KM, et al. Comparison of open and laparoscopic live donor left lateral sectionectomy. Br J Surg 2011;98:1302-8.
7. Wakabayashi G, Cherqui D, Geller DA, et al. Recommendations for laparoscopic liver resection: a report from the second international consensus conference held in Morioka. Ann Surg 2015;261:619-29.
8. Miller CM, Durand F, Heimbach JK, et al. The International Liver Transplant Society Guideline on Living Liver Donation. Transplantation 2016;100:1238-43.
9. Han HS, Cho JY, Kaneko H, et al. Expert Panel Statement on Laparoscopic Living Donor Hepatectomy. Dig Surg 2018;35:284-8.
10. Suh KS, Hong SK, Lee KW, et al. Pure laparoscopic living donor hepatectomy: Focus on 55 donors undergoing right hepatectomy. Am J Transplant 2018;18:434-43.
11. Park J, Kwon DCH, Choi GS, et al. Safety and Risk Factors of Pure Laparoscopic Living Donor Right Hepatectomy: Comparison to Open Technique in Propensity Score-matched Analysis. Transplantation 2019;103:e308-16.
12. Park JI, Kim KH, Lee SG. Laparoscopic living donor hepatectomy: a review of current status. J Hepatobiliary Pancreat Sci 2015;22:779-88.
13. Rhu J, Choi GS, Kim JM, et al. Feasibility of total laparoscopic living donor right hepatectomy compared with open surgery: comprehensive review of 100 cases of the initial stage. J Hepatobiliary Pancreat Sci 2020;27:16-25.
14. Gautier S, Monakhov A, Gallyamov E, et al. Laparoscopic left lateral section procurement in living liver donors: A single center propensity score-matched study. Clin Transplant 2018;32:e13374.
15. Kim WJ, Kim KH, Cho HD, et al. Long-Term Safety and Efficacy of Pure Laparoscopic Donor Hepatectomy in Pediatric Living Donor Liver Transplantation. Liver Transpl 2021;27:513-24.
16. Li HY, Wei L, Zeng ZG, et al. Laparoscopic left lateral sectionectomy in pediatric living donor liver transplantation by single-port approach: A case report. World J Clin Cases 2020;8:6103-9.
17. Li H, Zhu Z, Wei L, et al. Laparoscopic Left Lateral Monosegmentectomy in Pediatric Living Donor Liver Transplantation Using Real-Time ICG Fluorescence In Situ Reduction. J Gastrointest Surg 2020;24:2185-6.
18. Wei L, Zhang ZT, Zhu ZJ, et al. A New Approach to Accomplish Intraoperative Cholangiography in Left Lateral Segmentectomy of Living Liver Donation. Ann Transplant 2019;24:155-61.
19. Broering DC, Elsheikh Y, Shagrani M, et al. Pure Laparoscopic Living Donor Left Lateral Sectionectomy in Pediatric Transplantation: A Propensity Score Analysis on 220 Consecutive Patients. Liver Transpl 2018;24:1019-30.
20. Samstein B, Griesemer A, Halazun K, et al. Pure Laparoscopic Donor Hepatectomies: Ready for Widespread Adoption? Ann Surg 2018;268:602-9.
21. Soubrane O, de Rougemont O, Kim KH, et al. Laparoscopic Living Donor Left Lateral Sectionectomy: A New Standard Practice for Donor Hepatectomy. Ann Surg 2015;262:757-61; discussion 761-3.
22. Samstein B, Griesemer A, Cherqui D, et al. Fully laparoscopic left-sided donor hepatectomy is safe and associated with shorter hospital stay and earlier return to work: A comparative study. Liver Transpl 2015;21:768-73.
23. Bekheit M, Khafagy PA, Bucur P, et al. Donor safety in live donor laparoscopic liver procurement: systematic review and meta-analysis. Surg Endosc 2015;29:3047-64.
24. Brustia R, Komatsu S, Goumard C, et al. From the left to the right: 13-year experience in laparoscopic living donor liver transplantation. Updates Surg 2015;67:193-200.
25. Yang J, Kim JM, Rhu J, et al. Comparison of liver regeneration in laparoscopic versus open right hemihepatectomy for adult living donor liver transplantation. Ann Hepatobiliary Pancreat Surg

2020;24:33-7.
26. Cho HD, Samstein B, Chaundry S, et al. Minimally invasive donor hepatectomy, systemic review. Int J Surg 2020;82S:187-91.
27. Rhu J, Kim MS, Choi GS et al. A Novel Technique for Bile Duct Division During Laparoscopic Living Donor Hepatectomy to Overcome Biliary Complications in Liver Transplantation Recipients: "Cut and Clip" Rather Than "Clip and Cut". Transplantation 2021;105:1791-9.
28. de Ville de Goyet J, di Francesco F, Sottani V, et al. Splitting livers: Trans-hilar or trans-umbilical division? Technical aspects and comparative outcomes. Pediatr Transplant 2015;19:517-26.
29. Wei L, Zhi X, He E, et al. Prospective study on changes in the donor gallbladder contraction function after left lateral lobe hepatectomy. Pediatr Transplant 2019;23:e13395.
30. Kim YS, Choi SH. Pure Laparoscopic Living Donor Right Hepatectomy Using Real-Time Indocyanine Green Fluorescence Imaging. J Gastrointest Surg 2019;23:1711-2.
31. Humar A, Ganesh S, Jorgensen D, et al. Adult Living Donor Versus Deceased Donor Liver Transplant (LDLT Versus DDLT) at a Single Center: Time to Change Our Paradigm for Liver Transplant. Ann Surg 2019;270:444-51.

Cite this article as: Zhang HM, Wei L, Li HY, Sun LY, Qu W, Zeng ZG, Liu Y, Zhu ZJ. Impact of pure laparoscopic surgery on bile duct division of living donor left lateral section procurement. HepatoBiliary Surg Nutr 2023;12(3):328-340. doi: 10.21037/hbsn-21-418

Supplementary

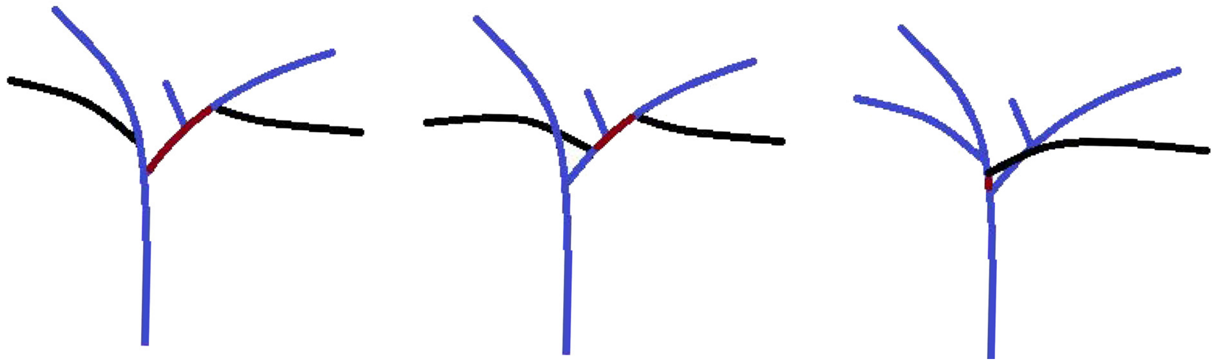

Figure S1 The length of each red area was defined as a value repenting the risk of multiple bile duct in graft. The red area in the right picture of the bile duct tree was defined as negative value.

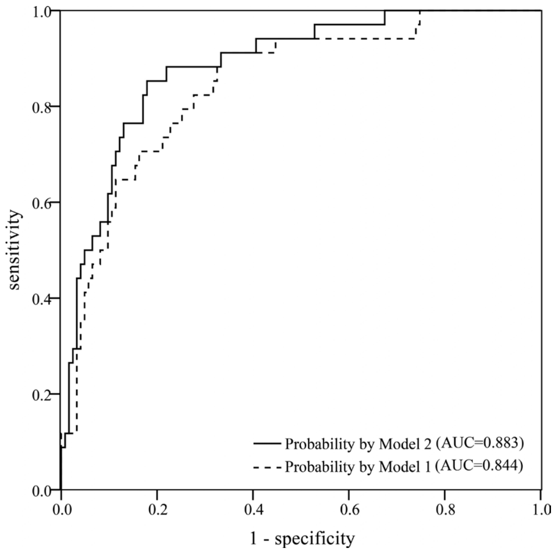

Figure S2 ROC curves of two logistic model for multiple biliary anastomoses.

https://dx.doi.org/10.21037/hbsn-21-418

Table S1 Baseline characteristics of donors and recipients after propensity matching

Characteristics	Open	Laparoscopic	P
n	52	52	
Age of recipient (year)	0.67, 0.33–6.00	0.83, 0.25–8.33	0.368
Gender of recipient			0.556
Male	23	26	
Female	29	26	
blood group of recipient			0.969
A	15	15	
AB	3	3	
B	12	14	
O	22	20	
Height of recipient (cm)	71.04±11.56	73.64±14.73	0.510
Weight of recipient (kg)	8.05, 5.00–22.00	8.15, 4.50–26.00	0.427
PELD score of recipient	14.13, −9.69–51.93	11.24, −9.82–51.55	0.658
Diagnosis			0.631
Acute hepatic failure	0	0	
Cholestasis disease	44	44	
Organic acidemia	2	1	
Tyrosinemia	0	1	
Urea cycle disorder	6	6	
Age of donor (year)	32.24±4.17	33.19±6.57	0.381
Gender of donor			0.327
Male	28	23	
Female	24	29	
Height of donor (cm)	167.40±8.23	167.65±7.71	0.873
Weight of donor (kg)	67.03±11.19	64.21±10.07	0.179
BMI of donor (kg/m^2)	23.71±3.30	22.83±3.13	0.167
Blood group of donor			0.517
A	13	15	
AB	2	4	
B	11	14	
O	26	19	
ABO blood group compatibly			1
Compatible	45	45	
Incompatible	7	7	

 https://dx.doi.org/10.21037/hbsn-21-418

Table S2 Perioperative characteristics of donor and recipient after propensity matching

Characteristics	Open	Laparoscopic	P
Cold ischemia time (h)	1.60, 0.33–4.43	1.40, 0.35–3.22	0.343
Operation time of recipient (h)	6.69±1.43	6.52±1.51	0.561
Blood loss of recipient (mL)	100, 30–345	150, 40–700	0.001
Operation time of donor (h)	4.16±1.25	3.28±1.00	<0.001
Blood loss of donor (mL)	150, 5–400	50, 20–800	0.001
Left lateral graft weight (g)	249.64±80.00	263.27±56.57	0.363
GRWR (%)	2.84, 0.96–6.00	3.06, 1.27–5.24	0.742
Common trunk length of left biliary tract (cm)	1.30, −0.5–2.83	1.21, −0.5–2.97	0.408
Number of hepatic artery anastomosed			0.415
1	35	31	
2	17	21	
3	0	0	
Number of biliary duct anastomosed			0.037
1	44	33	
2	7	18	
3	1	1	
Length of donor ICU stay (day)	1, 0–2	1, 0–2	0.729
Length of donor hospital stay (day)	7, 5–12	7, 5–10	0.857

Table S3 Average laboratory indexes of recipient and donor after propensity matching

Indexes	Open	Laparoscopic	P
Average level of recipient's laboratory indexes (0–2 days)			
AST (IU/L)	455.60, 141.20–2764.77	775.70, 167.70–2221.35	<0.001
ALT (IU/L)	492.00, 175.67–3443.00	761.00, 257.00–2165.50	<0.001
INR	1.48, 1.07–2.96	2.04, 1.06–3.26	<0.001
Average level of donor's laboratory indexes (0–2 days)			
AST (IU/L)	160.55, 58.05–582.20	202.03, 81.90–987.87	0.297
ALT (IU/L)	223.50, 76.00–819.00	284.50, 56.67–1329.33	0.109
TBIL(μmol/L)	27.58, 10.25–60.65	22.73, 10.09–78.19	0.067

https://dx.doi.org/10.21037/hbsn-21-418

Table S4 Surgical complications and survival of donor and recipient after propensity matching

Complications	Open	Laparoscopic	P
Recipient surgical complications (Clavien-Dindo grade III–IV)			0.426
No	45	42	
Yes	7	10	
90 days cumulative graft survival	98.1%	96.2%	0.552
1 year cumulative graft survival	98.1%	96.2%	0.552
1 year cumulative recipient survival	98.1%	96.2%	0.552
Donor surgical complications (Clavien-Dindo grade III–IV)			0.434
No	47	50	
Yes	5	2	
1 year cumulative donor survival	100%	100%	1

 https://dx.doi.org/10.21037/hbsn-21-418