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Original Article

# Selective hanging maneuver and rubber band retraction technique for pure laparoscopic donor right hepatectomy

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ABSTRACT

*Background:* Pure laparoscopic donor hepatectomy (PLDH) is an increasingly performed procedure despite its technical difficulties. This study introduced a selective liver parenchymal hanging maneuver and rubber band retraction technique for PLDH.

*Methods:* We retrospectively reviewed perioperative data from 58 patients who underwent donor right hepatectomy (including right extended) between March 2009 and February 2021. Eighteen patients underwent open donor right hepatectomy (ODRH) and 38 patients underwent pure laparoscopic donor right hepatectomy (PLDRH).

*Results:* All PLDRH donors underwent the procedure without the need for open conversion. The median PLDRH operative time was 396.84 ± 72.459 min, the median PLDRH intraoperative bleeding amount was 496.05 ± 272.591 ml, and the warm ischemic time was 8.77 ± 3.062 min. Compared to ODRH, laparoscopic surgery showed further advantages in terms of postoperative hospital stay (10.94 ± 4.036 days vs. 8.03 ± 2.646 days, respectively, P = 0.01) and estimated blood loss (676.67 ± 321.046 ml vs. 496.05 ± 272.591 ml, respectively, P = 0.033).

*Conclusions:* The selective liver parenchymal hanging maneuver and rubber band retraction technique is a simple and effective pure laparoscopic procedure for donor hepatectomy. Our results demonstrate the safety and feasibility of this technique.



## 1. Introduction

Living donor liver transplantation (LDLT) is a treatment option for patients with hepatocellular carcinoma and/or end-stage liver disease.[1] Using a right hepatectomy for donation has expanded the donor pool for adult patients who need large grafts.[2–4] In the past three decades, living adult to adult liver donation has become widely performed. Although donors are willing to donate their organs for transplantation, they still have to undergo unnecessary surgery that does not benefit their health.[3,4] After donor hepatectomy, they have postoperative pain, long postoperative recovery periods, and long abdominal scars.

Nowadays, many surgeons have started to perform pure laparoscopic donor hepatectomy (PLDH); however, only expert surgeons can perform PLDH because accurate anatomical understanding and advanced surgical skills are essential.[5–8] Since the first living donor hepatectomy was performed at our hospital in March 2009, the number of LDLT procedures performed annually was less than five until 2017. This was because our facility is small and surrounded by larger hospitals. Despite this, major complications and mortality have not occurred at our facility. After we started our PLDH program in November, 2018, we have performed PLDH for all donors.

This study aimed to introduce a pure laparoscopic donor right hepatectomy (PLDRH) procedure using a rubber band retraction technique and a selective hanging maneuver and to compare these outcomes with the outcomes of conventional open donor hepatectomy before the introduction of the PLDH program. Our final goal was to validate the safety and feasibility of PLDH.

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## 2. Materials and methods

The institutional review board (IRB) of Gangnam Severance Hospital approved this retrospective study (approval number. 3-2021-0039). Informed consent from patients was waived by IRB. All procedures in this study were performed in accordance with the relevant regulations and guidelines.

Between March 1, 2009, and February 28, 2021, 58 LDLT procedures were performed at Gangnam Severance Hospital. Eighteen patients received ODRH (including right extended), and 40 patients received pure laparoscopic donor hepatectomy. All open donor hepatectomies were ODRH. After the PLDH program started, 38 donors underwent PLDRH (including right extended) and two donors received pure laparoscopic left extended and caudate segmentectomy. These patients were excluded from the data analysis. The medical records of all donors and their recipients were retrospectively reviewed.

### 2.1. Operative procedure for PLDRH (Video)

The patients were placed in the reverse Trendelenburg position and semi-left lateral decubitus position. The surgeon stood on the left side of the patient and the scopist stood on the patient's lower left side.

Four ports were used for surgery. A camera port was inserted through the umbilicus. A 5-mm port was inserted via the infra xiphoid process site. A 12-mm port was inserted via the right mid-abdomen on the mid-clavicle line. A 5-mm assistive port was inserted via the inferior angle of the rib on the axilla line to provide operative field exposure. A carbon dioxide pneumoperitoneum was maintained at 13 mmHg (Fig. 1).

After liver biopsy from the liver dome angle of Cantlie's line, the gallbladder was removed and the right liver was mobilized. Connective tissue from the right lower side of the liver hilum was divided and the portal vein was exposed. The superior side of the portal vein was gently dissected using a right-angle dissector. The portal vein was encircled using a vessel lock. After extension of the dissection, the right and left portal veins were identified. The right or left hepatic artery was also exposed using a right-angle dissector. Exposure was extended to the bifurcation site of the proper hepatic artery to make the recipient-side hepatic artery as long as possible.

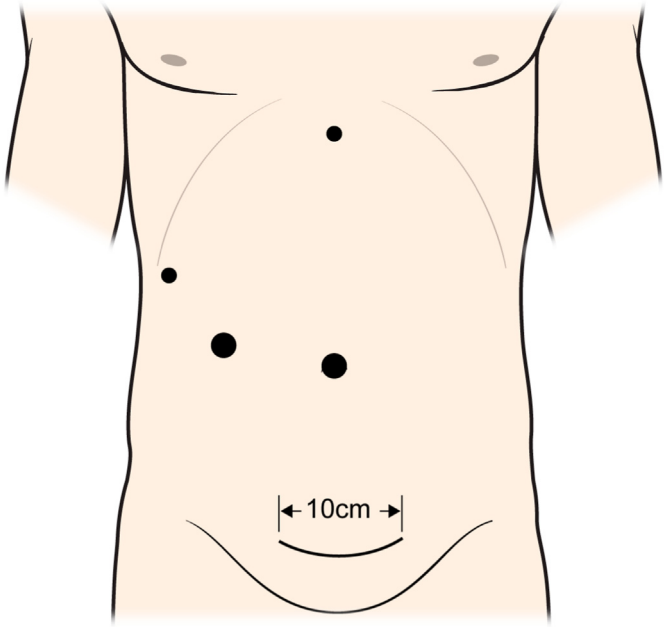


**Fig. 1.** The insertion site of the four trocars.

The right portal vein and right hepatic artery were clamped temporarily using a bulldog clamp. After identifying the boundary of the color change on the liver surface, a parenchymal transection line was drawn using a monopolar energy device. The rubber band was sutured to the edges of the liver on both sides of the drawn line, and both sides of the rubber band were pulled away from the drawn line. The liver parenchyma was carefully resected using an ultrasonic scalpel to a depth of less than 5 mm at a time when the risk of damage to the mid-hepatic vein was minimal.

After the liver parenchyma was transected until the superior surface of the right Glissonean pedicle was exposed, The gold finger retractor was inserted into the space between the vena cava and the paracaval portion of the caudate lobe. After the tips of the gold finger retractor penetrated the connective tissue between the middle hepatic vein and right hepatic vein, a silastic drain was inserted along the bare area track made by the gold finger retractor after the paracaval portion of the caudate lobe was divided up to the right Glissonean pedicle. The tip of the right-angle dissector was inserted into the transected liver parenchyma on the inferior edge of the right Glissonean pedicle and when it emerged from the parenchyma transection site on the superior edge of the right Glissonean pedicle, the silastic drain was inserted via this route and a selective hanging maneuver was performed (Fig. 2).

Both ends of the silastic drain were pulled out of the abdominal cavity through the infra xiphoid process port and transumbilical camera port to perform the selective hanging maneuver.

After completion of the selective hanging maneuver, liver parenchymal transection was completed. A suprapubic incision was made 10 cm longitudinally, and the abdominal fascia was opened vertically without opening the peritoneum to maintain pneumoperitoneum. After intraoperative cholangiography using the cystic duct and/or indocyanine green fluorescence cholangiography was performed, a near-infrared light was used to confirm the bile duct cutting line, and the right hepatic duct was transected without the left hepatic duct whilst avoiding common hepatic duct injury. After heparinization, proximal site of the right hepatic artery and the right portal vein was ligated and transected using purple hemo-o-lock and transected after checking for intact left vessels flow. The right hepatic vein was then divided with a laparoscopic vascular stapler.

### 2.2. Statistical analysis

All continuous data were expressed as means with standard deviations. Categorical data were expressed as numbers and percentages. A Student's t test was used to compare continuous variables. The chi-square test or Fisher's exact test was used to compare categorical variables, as appropriate. A Pearson's test was used to test the significance of the correlation. A two-tailed $P < 0.05$ was considered statistically significant. Statistical analyses were performed using IBM SPSS software (version 25; IBM Inc., Chicago, IL).

## 3. Results

### 3.1. Characteristics and outcomes of PLDRH

The clinical records of PLDRH patients were reviewed and analyzed (Table 1). Among them, 28 donors underwent PLDRH and 10 donors underwent pure laparoscopic right extended hepatectomy (including the middle hepatic vein). There were no open conversions and no additional port insertions. One donor received an intraoperative transfusion due to right hepatic vein stump

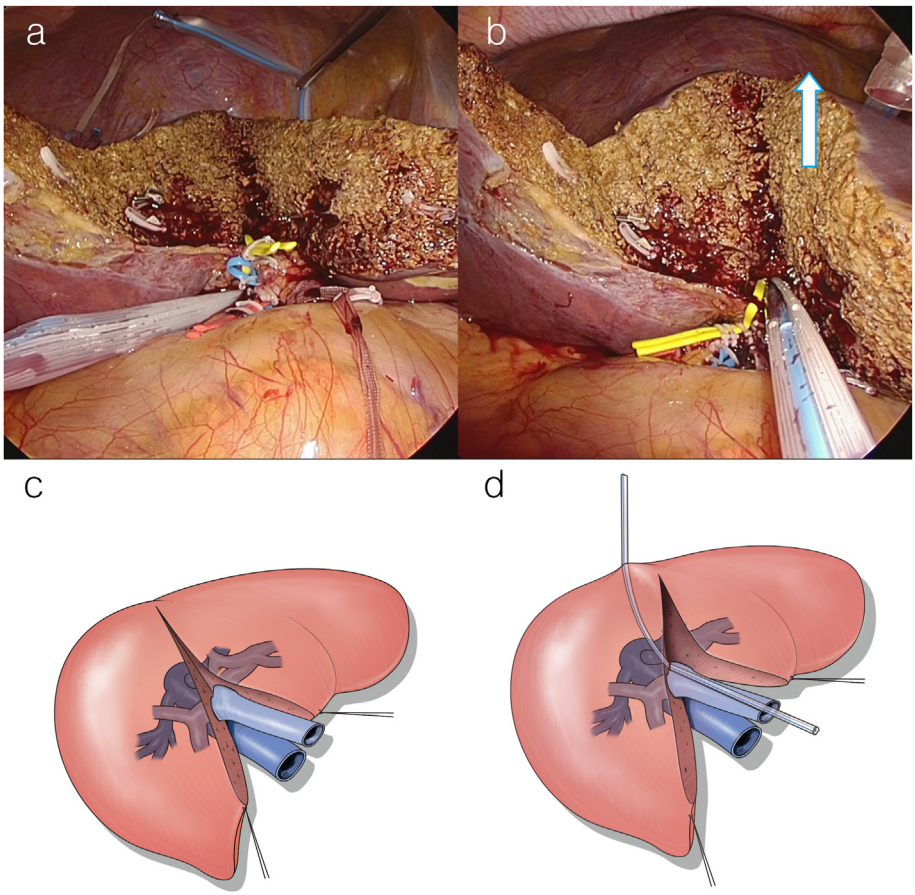


**Fig. 2.** Picture and schematic view of before and after the selective hanging maneuver
a. Picture before the selective hanging maneuver; b. Picture after the selective hanging maneuver. the liver parenchyma on the liver dome side is pulled toward the xiphoid process trocar direction (arrow); c. Schematic view before the selective hanging maneuver; d. Schematic view after the selective hanging maneuver.

bleeding. The median amount of intraoperative bleeding was 496.05 ± 272.591 ml. The median operative time was 396.84 ± 72.459 min and the warm ischemic time was 8.77 ± 3.062 min.

A perioperative complication of Clavien-Dindo classification III or higher occurred in one patient. One patient had right pleural effusion and bile leakage on postoperative day 3. On endoscopic retrograde cholangiopancreatography (ERCP), minimal bile leak was found at the right hepatic duct resection site. Bile leak was controlled after stent insertion using ERCP. After this case, additional intraoperative cholangiogram procedures were performed after recipient side hepatic duct ligation to check for bile leak and bile duct patency.

### 3.2. Analysis of operative time for PLDRH

For analysis of the learning curve, the duration of the procedure was divided into six parts: time for right lobe mobilization; time for right portal vein and right hepatic artery isolation; time for liver parenchymal transection; warm ischemic time; time to removal of the donor liver; and total operative time. All procedure times showed a linearly decreasing pattern except for the duration of right portal vein and right hepatic artery isolation (Fig. 3).

### 3.3. Comparison of open donor right hepatectomy (ODRH) and PLDRH

The baseline patient characteristics did not differ between the ODRH and PLDRH groups (Table 1). Postoperative hospital stays were longer and estimated intraoperative blood loss was greater in ODRH patients. Intraoperative blood transfusion was needed only in PLDRH patients, although there was no statistically significant difference in the rates between the two groups. In terms of complications, there was no significant difference between the two groups. However, one patient in the PLDRH group received ERCP and catheter was inserted because of bile leak.

In recipients, the complication rate and 60-day mortality rate did not differ between the two groups. However, bile leakage occurred in four recipients who received a liver from donors who underwent PLDRH. Bile leakage was controlled after ERCP in all patients. Postoperative 60-day recipient mortality occurred in six patients. In the ODRH group, one patient died on postoperative day 16 because of a primary non-functioning liver. Another patient died due to massive bleeding on postoperative day 39. In the PLDRH group, two patients died on postoperative day 2 because of massive bleeding due to disseminated intravascular coagulation. One patient presented with acute rejection. Another had sepsis before liver transplantation. Portal vein stenosis and/or outflow disturbance of the hepatic vein did not occur in any patient.

## 4. Discussion

Nowadays, PLDH is widely accepted and many reports have been published that highlight the advantages of laparoscopic procedures in terms of minimized invasiveness for healthy donors.[9–11] Laparoscopic donor hepatectomy leads to less operative blood loss and shorter hospital stays than open donor hepatectomy.[7,11,12]

**Table 1**
Liver volume and GRWR comparison of open donor right hepatectomy and pure laparoscopic donor right hepatectomy.

| Variables | ODRH | PLDRH | P-value |
|---|---|---|---|
| Gender, male: female | 7 : 11 | 19 : 19 | 0.436 |
| Age, mean ± SD, years | 29.50 ± 10.706 | 33.84 ± 12.084 | 0.199 |
| BMI, mean ± SD, kg/m$^2$ | 22.46 ± 2.110 | 23.516 ± 2.317 | 0.110 |
| ASA score | 1.22 ± 0.428 | 1.21 ± 0.413 | 0.922 |
| Relationship, n (%) | | | |
| Son/daughter | 14 (77.8%) | 29 (76.3%) | 0.904 |
| Father/mother | 0 (0%) | 1 (2.6%) | 1.000 |
| Brother/sister | 3 (16.7%) | 1 (2.6%) | 0.093 |
| Husband/wife | 1 (5.6%) | 5 (13.2%) | 0.652 |
| Operation type, n(%) | | | 1.000 |
| Right hepatectomy | 13 (72.2%) | 28 (73.7%) | |
| Right extended hepatectomy | 5 (27.8%) | 10 (26.3%) | |
| Estimated GRWR | 1.31 ± 0.362 | 1.15 ± 0.320 | 0.108 |
| Remnant donor liver volume (mm$^3$) | 441.55 ± 54.289 | 428.93 ± 72.516 | 0.515 |
| Graft weight (g) | 716.50 ± 111.061 | 677.07 ± 140.646 | 0.304 |
| Open conversion, n | 0 | Not applicable | |
| Additional port insertion, n | 0 | Not applicable | |
| Operation time, mean ± SD, min | 405.22 ± 78.894 | 396.84 ± 72.459 | 0.624 |
| Time to remove liver, mean ± SD, min | 256.86 ± 51.250 | No data | |
| Warm ischemic time, mean ± SD, min | 8.77 ± 3.062 | No data | |
| Double portal vein orifice, n (%) | 0 | 2 | |
| Estimated blood loss, mean ± SD, ml | 676.67 ± 321.046 | 496.05 ± 272.591 | 0.033 |
| Intraoperative transfusion, n (%) | 0 | 1 | |
| Postoperative hospital stay, mean ± SD, days | 10.94 ± 4.036 | 8.03 ± 2.646 | 0.010 |
| Rehospitalization, n (%) | 0 | 0 | |
| Postoperative complications, n | 1 (5.6%) | 1 (2.6%) | 0.544 |
| Pleural catheter insertion | 1 (5.6%) | 1 (2.6%) | 0.544 |
| Bile leakage | 0 (0%) | 1 (2.6%) | 1.000 |
| Recipient complications | 6 (33.3%) | 10 (26.3%) | 0.587 |
| IIIa | 3 (16.7%) | 5 (13.2%) | 0.703 |
| Right pleural effusion | 2 (11.1%) | 2 (5.3%) | 0.587 |
| Bile leakage | 1 (5.6%) | 4 (10.5%) | 1.000 |
| IIIb | 1 (5.6%) | 1 (2.6%) | 0.544 |
| Bleeder ligation | 1 (5.6%) | 0 (0%) | 0.321 |
| Artery re-anastomosis | 0 (0%) | 1 (2.6%) | 1.000 |
| IV (90-day mortality) | 2 (11.1%) | 4 (10.5%) | 1.000 |

ODRH, open donor right hepatectomy; PLDRH, pure laparoscopic donor right hepatectomy; SD, standard deviation; BMI, body mass index, ASA, American Society of Anesthesiologists.

However, in terms of minimal risk to the healthy donor, laparoscopic donor hepatectomy has not been well accepted due to concerns about donor safety and technical difficulty. It still tends to be performed by expert surgeons at large centers.[13,14] In particular, institutions that perform less than 10 living donor liver transplantations per year are hesitant to apply laparoscopic procedures because of the safety of the donor, and sufficient volume and adequate vessel length for the recipient.[14,15]

The rubber band retraction technique uses an elastic rubber band to pull both side edges of the resection line in the opposite direction.[16–20] This technique provides stable retraction without the concern of iatrogenic injury by an inexperienced assistant. Particularly in laparoscopic procedures, a self-retracting system using a rubber band can decrease the number of trocar insertions. It only requires a needle-size puncture site for the rubber band to pass through. However, in deep liver parenchymal transection near the inferior vena cava (IVC), exposure may be insufficient using the rubber band retraction technique. Another method, such as the use of a retractor or an additional instrument for exposure, must be employed for exposure of the transection field.[16,19]

The hanging maneuver was introduced by Belghiti et al and is now widely used during major hepatectomy.[21] Kokudo et al developed and proposed the hanging maneuver repositioning technique.[22] Many laparoscopic donor hepatectomy procedures are performed using bile duct and hilar plate resection for exposure of the caudate parenchyma.[20,23,24] However, a repositioned hanging tape behind the hepatic hilum allows easy completion of parenchymal transection before dividing the bile duct and the hilar plate. It facilitates the saving of the donor liver in situations of inevitable cessation of donor hepatectomy according to the state of the recipient. The repositioning technique also decreases inflow and outflow obstruction of the graft side of the liver. Like the Kokudo method, we performed a parenchymal selective hanging maneuver. This technique was almost the same, but without mid-hepatic branch preservation during parenchymal transection.

In laparoscopic hepatectomy procedures, the camera is usually used with a trocar at the periumbilical area. This provides a caudal view during laparoscopic hepatectomy instead of the cranial view used during open hepatectomy.[14,25] The hanging maneuver in laparoscopic hepatectomy changes the liver parenchymal transection line from the caudal view to the cranial view, as in an open procedure. In laparoscopic procedure, the portal pedicle can also be damaged when an energy device is used to transect the liver parenchyma behind the portal pedicle. The use of a repositioned hanging tape for the selective hanging maneuver can lead to a barrier when performing liver parenchymal transection behind the portal pedicle using an energy device.[22] The selective hanging maneuver allows safe parenchymal transection of the retrohepatic portion without dividing any structures of the hilar plate.

We performed a rubber band retraction technique and selective hanging maneuver in all cases. The total operative time and time for liver parenchymal transection were markedly decreased because the selective hanging maneuver directly shows the liver parenchymal transection line and the silicon drain protects against injury to the portal pedicle by the energy device. However, the duration of right portal vein and right hepatic artery isolation did not show a

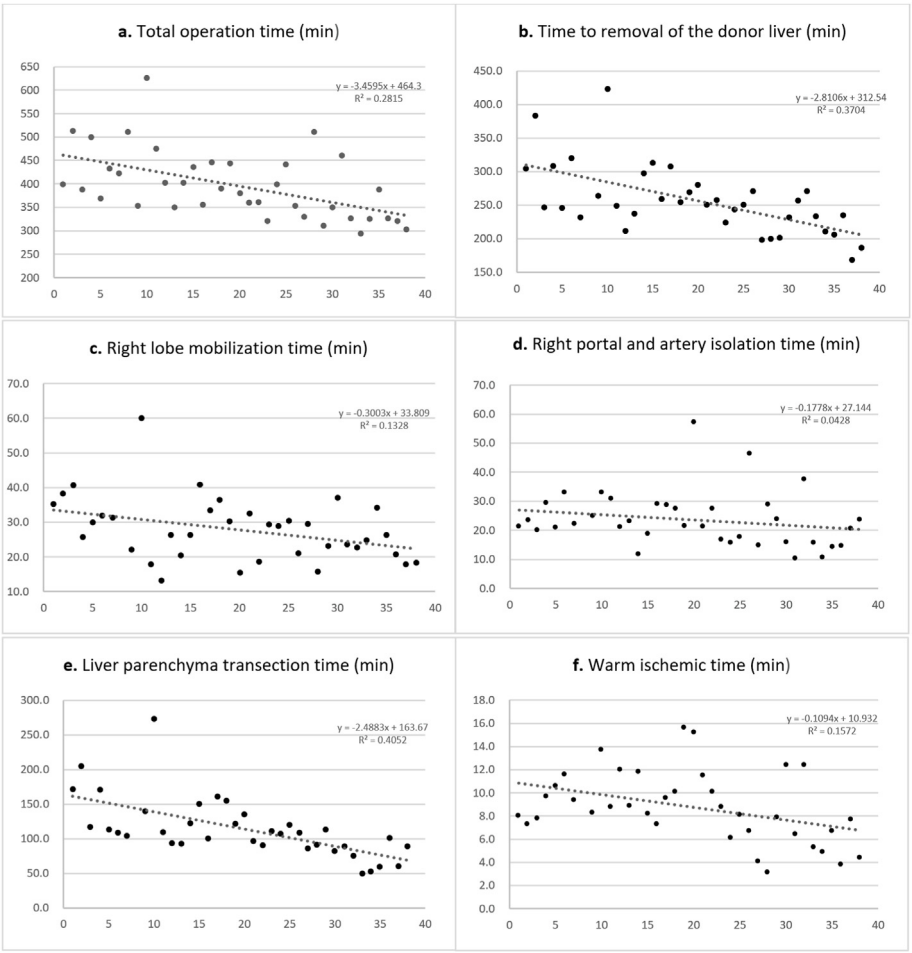


**Fig. 3.** Correlation of procedure time and cumulative case number for a single surgeon
**a.** Learning curve of total operative time ($\rho = -3.4595$, $R^2 = 0.2815$, $P = 0.001$); **b.** learning curve of time to removal of the donor liver ($\rho = -0.2811$, $R^2 = 0.3704$, $P < 0.001$); **c.** learning curve of time for right lobe mobilization ($\rho = -0.3003$, $R^2 = 0.1328$, $P = 0.027$); **d.** learning curve of time for right portal and artery isolation ($\rho = -0.1778$, $R^2 = 0.0428$, $P = 0.219$); **e.** learning curve of time for liver parenchyma transection ($\rho = -0.2488$, $R^2 = 0.4052$, $P < 0.001$); **f.** learning curve for warm ischemic time $\rho = -0.1094$, $R^2 = 0.1572$, $P = 0.015$).

significant linearly decreasing pattern. This seems to be due to the variations in the portal vein and hepatic artery anatomy from one patient to another. In our study periods, two patients showed trifurcation of the portal vein, and another two patients presented with an aberrant right posterior hepatic artery.

In the PLDRH group, four recipients experienced bile leak complications. All bile leaks were resolved after ERCP. The rate of bile leaks after transplantation has been reported to be 2%–25%.[26] Our incidence rate was 10.5%. Before the PLDH program, we had only seen one bile leak incident after transplantation. Rhu et al reported a larger bile duct opening than expected in the early period of laparoscopic PLDRH.[24] They showed that there was no difference based on the size of the bile duct opening in 48 patients undergoing their first PLDRH. Before starting the laparoscopic PLDH, sufficient discussion between the transplant surgeon and the donor surgeon is needed. The recipient 90-day mortality rate is 10.7% in our hospital. However, there was no mortality associated with small for size syndrome or donor vessel problems, except in one case in the ODRH group.

This study had several limitations. First, the PLDRH procedures in study period were performed by an inexperienced single surgeon. During an inexperienced surgeon's learning period, unexpected events may occur and the operative procedure may need to be changed. However, surgeon have more than 100 laparoscopic major hepatectomies experiences and had undertaken training for PLDH in other big hospital before starting to perform PLDH. There is no change of operative procedure in study period. Second, the retrospective design and small sample size may limit the statistical strength of the findings and the generalization of the results.

## 5. Conclusion

Donor hepatectomy requires completion of liver parenchymal transection and preservation of the hepatic vessel and hepatic duct. Given this, the rubber band method and selective hanging maneuver are good methods for PLDRH without the need for more instruments. We successfully performed 38 PLDRH procedures without the need for open conversion. After the first PLDRH, all donors received laparoscopic donor hepatectomy without exception. Donors who undergo PLDRH have shorter postoperative hospital stays and less intraoperative blood loss than donors who undergo ODRH.

## Author contributions

Man Ki Ju: Conception and design of study, Acquisition of data, Data analysis and interpretation, Drafting of manuscript and critical revision, Approval of final version of manuscript.

Sung Hwan Yoo: Acquisition of data, Data analysis and interpretation, Drafting of manuscript and critical revision, Approval of final version of manuscript.

Ki Hong Choi: Drafting of manuscript and critical revision, Approval of final version of manuscript.

Dong Sub Yoon: Drafting of manuscript and critical revision, Approval of final version of manuscript.

Jin Hong Lim: Conception and design of study, Drafting of manuscript and critical revision, Approval of final version of manuscript.

## Declaration of competing interest

The authors (Ju Man Ki, Sung Hwan Yoo, Gi Hong Choi, Dong Sub Yoon, Jin Hong Lim) declare no competing interests.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.asjsur.2023.08.227.

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