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Pure laparoscopic living donor liver transplantation: Dreams come true

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Abbreviations

BMI, body mass index; CT, computed tomography; HCC, hepatocellular carcinoma; IVC, inferior vena cava; LDLT, living donor liver transplantation; LT, liver transplantation; MELD, model for end-stage liver disease; MHV, middle hepatic vein; PTFE, polytetrafluorethylene; RHV, right hepatic vein

Abstract

Minimally invasive approaches are increasingly being applied in surgeries and have recently been used in living donor hepatectomy. We have developed a safe and reproducible method for minimally invasive living donor liver transplantation, which consists of pure laparoscopic explant hepatectomy and pure laparoscopic implantation of the graft, which was inserted through a suprapubic incision. Pure laparoscopic explant hepatectomy without liver fragmentation was performed in a 60-year-old man with alcoholic liver cirrhosis and hepatocellular carcinoma. The explanted liver was retrieved through a suprapubic incision. A modified right liver graft, procured from his 24-year-old son using the pure laparoscopic method, was inserted through a suprapubic incision, and implantation was performed intracorporeally throughout the procedure. The time required to remove the liver was 369 minutes, and the total operative time was 960 min. No complications occurred during or after the surgery. The patient recovered well, and his hospital stay was of 11 days. Pure laparoscopic living donor liver transplantation from explant hepatectomy to implantation was performed successfully. It is a feasible procedure when performed by a highly experienced surgeon and transplantation team. Further studies with larger sample sizes are needed to confirm its safety and feasibility.

1 Introduction

A laparoscopic approach is increasingly being adopted in various fields of surgery due to its potential benefits over the open approach, such as a reduced abdominal wound, lesser pain, and shorter hospital stay.[1,2] Laparoscopic liver resection in patients with cirrhosis also offers the advantages of reduced postoperative complications, pain, and duration of hospital stay, with oncological results similar to those obtained with open liver resection.[3-6] Furthermore, many recent studies have reported the use of laparoscopic and robotic donor hepatectomies, which are technically challenging.[7-11] Laparoscopic and robotic pancreatoduodenectomies, including those that require vascular reconstruction, are also being increasingly performed.[12-15] However, to date, there have been no published reports of pure laparoscopic or laparoscopy-assisted liver transplantation (LT). Living donor liver transplantation (LDLT) consists of explant hepatectomy and implantation of a partial liver graft from a living donor, and requires reconstruction of the hepatic vein, portal vein, hepatic artery, and bile duct.

With an experience of more than 1,000 open donor hepatectomies, 60 laparoscopy-assisted donor hepatectomies, and 200 laparoscopic hepatectomies in patients with tumors, the surgeon in this study has performed pure laparoscopic donor hepatectomies since November 2015. Our center, the Seoul National University Hospital, has performed more than 400 pure laparoscopic donor hepatectomies (mostly comprising right hepatectomies) and more than 2,300 LTs (including approximately 1,600 cases of LDLTs). Based on the experience of the surgeon and the team, we initiated a minimally invasive LDLT program in March 2020, and successfully performed pure laparoscopic explant hepatectomies and graft implantations using an upper midline incision as the first step of the program.[16] In the next stage of the program, we successfully performed pure laparoscopic LDLTs, including both explant hepatectomy and reconstruction of the vessels and bile duct.

Herein, we present our first experience of a pure laparoscopic LDLT performed using a suprapubic incision, which was used for native liver retrieval and implantation of the donor's partial liver graft. To the best of our knowledge, there has been no previous report of a pure laparoscopic LDLT comprising explant hepatectomy and implantation of the graft with reconstruction of the vessels and bile duct.

2 Materials and methods

The institutional review board of Seoul National University Hospital approved this study (IRB no.: 2003-019-1106). A 60-year-old man required a liver transplant for alcoholic liver cirrhosis and hepatocellular carcinoma (HCC). Endoscopic variceal ligation was performed once, and transarterial chemoembolization was performed 3 times prior to LDLT. The computed tomography (CT) scan taken immediately before surgery did not reveal an HCC; however, it revealed a probable bland thrombus along the right and main portal veins and a small amount of ascites (Figure 1). Mild perigastric and paraesophageal varices were identified, but there was no definite splenorenal shunt. The patient's height, weight, and body mass index (BMI) were 168.5 cm, 75.8 kg, and 26.7 kg/m^2, respectively. The Child–Pugh score was 5, and the Model for End-Stage Liver Disease (MELD) score was 8.3. The donor was his 24-year-old son, who donated a part of his liver. The donor's height, body weight, and BMI were 173.0 cm, 72.0 kg, and 24.1 kg/m^2, respectively. According to preoperative CT, the estimated remnant liver volume was 43% and the graft-to-recipient weight ratio (GRWR) was 0.84. Preoperative magnetic resonance cholangiopancreatography revealed a fat fraction of 4.2% and conventional bile duct anatomy.

The recipient, donor, and their families were informed of the innovative nature of the procedure and the advantages and disadvantages of pure laparoscopic LDLT.

Surgical procedure

The surgical procedure has been demonstrated in Video S1. The donor's right liver was procured using the pure laparoscopic method, which is currently the standard procedure in our center.[7,8,17–19]

Pure laparoscopic LDLT can be divided into 2 main steps: pure laparoscopic explant hepatectomy and pure laparoscopic graft implantation. The first step, pure laparoscopic explant hepatectomy, has been described in detail previously.[16] The patient was placed in supine and reversed Trendelenburg positions with the legs apart. Five 12-mm trocars were used, as shown in Figure 2B. Pneumoperitoneum was maintained at 12 mmHg. A laparoscopic view was obtained using an Endoeye Flex 3D laparoscope (Olympus, Tokyo, Japan). The left portal flow-preserving hilar dissection method was used to perform explant hepatectomy similar to in the open technique, which excludes liver fragmentation.[2,16] The explanted whole liver was placed in an endo-bag and

retrieved via a 12-cm suprapubic incision. A GelPort (Applied Medical, Rancho Santa Margarita, CA, USA) was applied to this transverse incision for use as a hand port in case of emergent situations (Figure 2C).

The hepatic arteries were prepared and temporarily clamped with small laparoscopic bulldog clamps. The thrombus in the portal vein was removed, and the distal part of the portal vein was temporarily double-clamped with 2 laparoscopic bulldog clamps. A Chitwood clamp was inserted through a small incision in the left upper quadrant for suprahepatic inferior vena cava (IVC) clamping (Figure 2D); the infrahepatic IVC was clamped using 2 laparoscopic bulldog clamps. The recipient right hepatic vein (RHV) opening was enlarged with an additional incision after measuring its longitudinal dimension, in order to match the sizes of the graft RHV and the reconstructed middle hepatic vein (MHV).

Cold gauze with ice was placed under the right diaphragm for positioning of the liver graft. Then, the modified right liver graft from the donor, with MHV reconstruction using polytetrafluorethylene (PTFE), was placed in an endo-bag and inserted through the same incision. After positioning the liver graft, the common opening between the graft RHV and the PTFE-reconstructed MHV was anastomosed to the recipient's enlarged RHV opening using 4-0 Prolene continuous suture. Considering the size of the openings and the distance between the recipient's portal vein and the graft, the recipient's left portal vein opening was ligated with the clip and the right portal vein opening was anastomosed to the graft portal vein using 6-0 Prolene continuous suture. After reperfusion, the recipient's middle hepatic artery was anastomosed to the graft hepatic artery using 7-0 Prolene interrupted sutures. Finally, the recipient's right hepatic duct was anastomosed to the graft bile duct using a 6-0 Prolene continuous suture, and the left hepatic duct was suture-ligated. The port sites were closed after meticulous hemostasis and drain insertion.

3 Results

The liver removal time was 369 min, and the total operative time was 960 min. The times required for the anastomosis of the hepatic vein, portal vein, hepatic artery, and bile duct were 42, 34, 49, and 45 min, respectively. Warm ischemic time, defined as the time from removal of the graft from ice to reperfusion, was 84 min. The times spent for each procedure are summarized in detail in Figure 3. Right portal vein clamping with left portal flow-preservation was maintained for 75 min.

The entire portal vein was clamped for 212 min. The estimated blood loss was 3,300 ml and 5 packs of red blood cells were transfused during the operation. With a graft weight of 703.5 g, the real GRWR was 0.9%. Protocol CT performed on postoperative day 7 revealed patent vascular structures without any abnormal findings. The patient was discharged on postoperative day 11 with no complications.

The results of all blood tests performed from before LDLT to the discharge day are shown in Figure 4. The suprapubic transverse wound could be hidden by the underwear. Furthermore, the 5 port sites and the Chitwood clamp insertion site were barely visible (Figure 2D).

4 Discussion

We have developed and described a safe, reproducible, and minimally invasive LDLT technique consisting of pure laparoscopic explant hepatectomy and pure laparoscopic implantation of the graft, which was inserted through a suprapubic incision.

Our center has run a minimally invasive LDLT program for recipients since March 2020. We recently reported our first successful pure laparoscopic explant hepatectomy (without liver fragmentation) and implantation of a modified right liver graft from a living donor using an upper midline incision.[16] The explant hepatectomy was performed in the same manner as the conventional open technique using the left portal flow-preserving hilar dissection method.[16] Since then, after confirming the safety and feasibility of this hybrid technique in LDLT by consecutive successful cases,[16] we performed the first pure laparoscopic LDLT including both, an explant hepatectomy and a purely laparoscopic graft implantation.

Several factors were involved in our patient selection. First, the patient had ascites, a relatively atrophied liver with underlying alcoholic liver cirrhosis, and a big belly. Furthermore, the graft liver was not large (estimated liver volume: 615 ml and estimated GRWR: 0.84). These factors provided enough working space, which might have helped in the explantation of the native liver and implantation of the graft liver. Second, the patient had esophageal and perigastric varices. The presence of a varix or shunt may prevent bowel congestion, which may otherwise result in sudden narrowing of the working space during the left portal flow-preserving hilar dissection. Dissecting the IVC and the liver, particularly the left liver, is a difficult step during the procedure. Though

dividing the hilum first may help in IVC and liver dissection, it may also result in bowel congestion. From this perspective, the presence of varices and division of the right side of the hilum, while preserving the left side, balance the need for IVC and liver dissection with the need for preventing bowel congestion.

Catastrophic events may occur during LDLT, even with the open technique. Preparation for these potential catastrophic events is essential. First, we applied a GelPort to the suprapubic incision, so that hand assistance would be possible whenever needed (such as for sudden bleeding control, positioning of the liver graft, and suturing of the vessels or bile duct). Second, a Chitwood clamp and multiple laparoscopic bulldog clamps were applied to clamp the major vessels securely. The retrocaval space was carefully dissected and encircled. The upper part of the IVC was clamped using a Chitwood clamp, which was inserted from the outside of the abdomen. The lower part of the IVC and the portal vein were clamped using laparoscopic bulldog clamps, rather than with an additional Chitwood clamp, from the outside of the abdomen. Multiple external long clamps may narrow the space and interfere with the operator's laparoscopic instruments, making laparoscopic suturing difficult. Laparoscopic bulldog clamps are relatively stronger than open bulldog clamps, and 2 laparoscopic bulldog clamps were used for the IVC and portal vein, in case of accidental slippage.

The possible benefit of pure laparoscopic LDLT may be the smaller incision as compared to the inverted "L" or Mercedes incision in the open technique. The pure laparoscopic LDLT technique in this study required only 5 12-mm port incisions and one Chitwood clamp insertion site, which were barely visible 2 weeks after LT, and a suprapubic incision for native liver retrieval and graft liver insertion (Figure 2D). Absence of a large upper abdominal wound may help in postoperative lung care and prevent wound hematoma, infection, and incisional hernia. This benefit may be similar to that obtained with pure laparoscopic donor hepatectomy. Regarding pure laparoscopic donor hepatectomy, in one study, although the total operation time was longer, the length of postoperative hospital stay was significantly shorter in the pure laparoscopic group than in the open group, while the rates of complications were similar.[7,8] Moreover, better wound satisfaction was observed in donors who underwent hepatectomy using the pure laparoscopic method as compared to in those in whom the open approach was used.[20] Similar results were observed in the recipients. Rapid rehabilitation, early recovery, and early return to everyday life (in terms of short-term outcomes) and self-confidence with wound satisfaction (in terms of long-term outcomes)

may be the main potential benefits of pure laparoscopic LDLT.

The major limitation of this technique is the long operation time. More time was needed for positioning the graft liver, controlling the bleeding, and suturing as compared to that required in the open technique. The warm ischemic time was 84 minutes; in the past 5 years, LDLT at our center required a mean of 33 minutes when performed using the open technique. The patient recovered well without any complications and was discharged on postoperative day 11. Accumulation of experience may shorten the warm ischemic and total operation times. The learning curve effect was also clearly assessed in pure laparoscopic living donor right hepatectomy.[7,17,21] To minimize the suturing time for reconstruction of the vessels and bile duct, a robotic system may be helpful. Several studies have reported the safety and feasibility of robotic pancreaticoduodenectomy.[22,23] Robotic pancreaticoduodenectomy showed surgical and oncological outcomes similar to those in open pancreaticoduodenectomy.[22,23] A Korean study demonstrated that laparoscopic and robotic hybrid pancreaticoduodenectomies showed operation times similar to those in open pancreaticoduodenectomy.[22] Considering the wide range of motion required during explant hepatectomy, laparoscopic procedures may be better than robotic procedures. Conversely, graft implantation, which includes vascular and bile duct anastomosis, may be more easily performed under robotic than under laparoscopic procedures.

Another major drawback of this study was that it involved a single case. Nevertheless, there have been no previous reports of pure laparoscopic LDLT comprising both, a pure laparoscopic explant hepatectomy and graft implantation. Additional experience in carefully selected patients is needed to properly evaluate the clinical benefits of this approach. For now, this novel procedure should be performed for laparoscopic hepatectomy and LDLT, preferably by a highly experienced team. Furthermore, only a small number of cases (selected carefully in terms of not only the recipient disease and morphology, but also the graft anatomy) must be subjected to this procedure for now.

In conclusion, this study showed the feasibility of a pure laparoscopic approach for LDLT, when performed by a surgical team with significant expertise in laparoscopic surgeries and LDLT. More experience using the hybrid approach, pure laparoscopic explant hepatectomy, and robotic graft implantation may allow the drawing of solid conclusions on the safety and feasibility of minimally invasive LDLT.

Disclosure

The authors of this manuscript have no conflicts of interest to disclose as described by the *American Journal of Transplantation*

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author.

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Figure Legends

Figure 1. Preoperative computed tomography images. (A) Bland portal vein thrombus. (B) Gastric and paraesophageal varices.

Figure 2. (A) Position of the patient, surgeons, and monitors. (B) Position of the ports. (C) Application of the GelPort (Applied Medical, Rancho Santa Margarita, CA) to the transverse incision after graft insertion. (D) Abdominal wounds of the donor and recipient 2 weeks postoperatively.

Figure 3. A detailed timeline of the procedure. HV, hepatic vein; PV, portal vein; HA, hepatic artery; BD, bile duct

Figure 4. Blood test results from before liver transplantation (LT), at LT, and at discharge from the hospital. AST, aspartate aminotransferase; ALT, alanine aminotransferase; Hb, hemoglobin; T.bil, total bilirubin; PT, prothrombin time; INR, international normalized ratio

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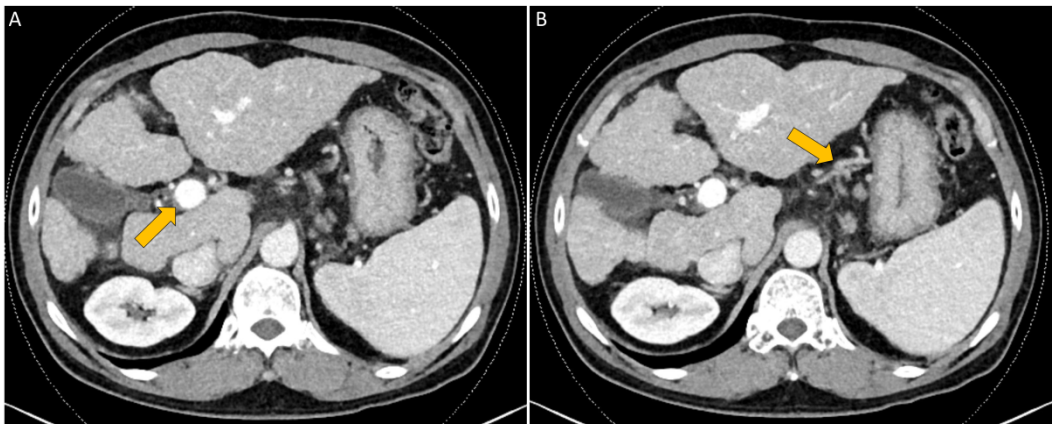

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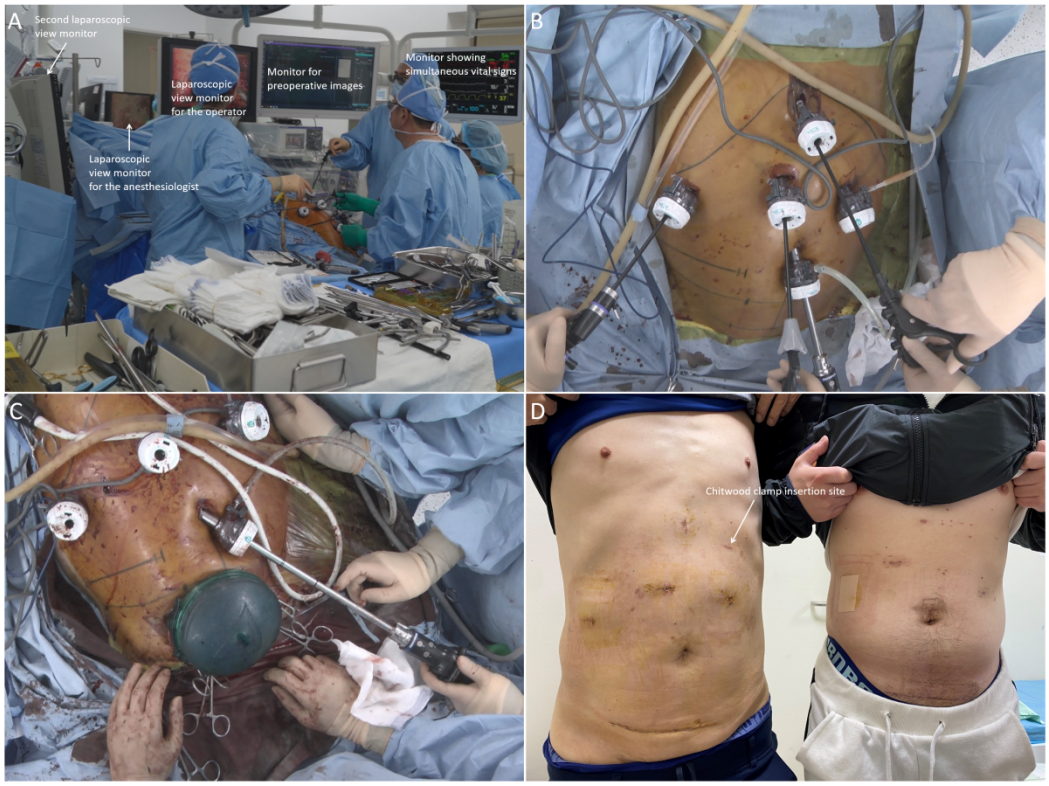

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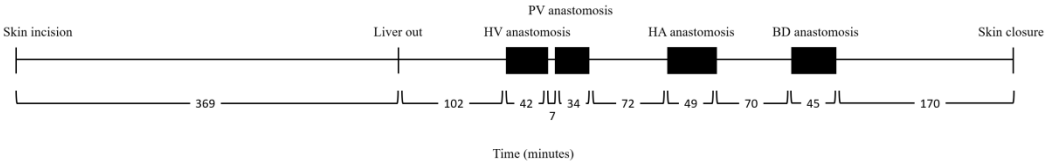

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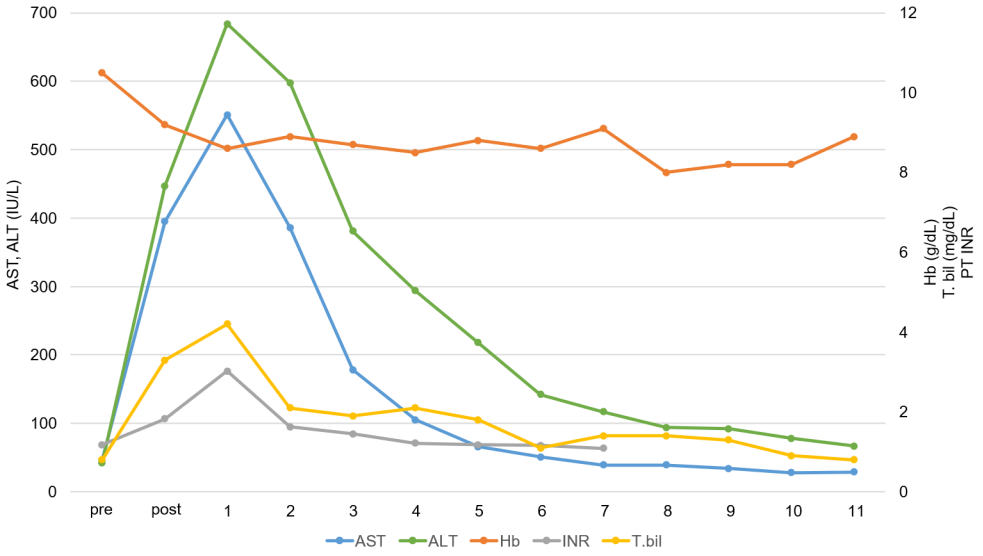

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