

Laparoscopic unroofing for hepatic cysts compressing the left portal vein, partial TIPE ALPPS, and hepatic vein deprivation to overcome a small future liver remnant before right hemihepatectomy

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Abstract: Preoperative portal vein embolization (PVE) is widely used to induce hypertrophy of the future liver remnant (FLR) before major hepatectomy. However, in cases of impaired portal flow in the FLR, conventional preoperative PVE may fail to achieve sufficient hypertrophy. A 76-year-old woman presented with intrahepatic cholangiocarcinoma involving the right Glissonean sheath. The FLR volume was 21.9% of the total liver volume, indicating the need for preoperative liver regeneration before right hemihepatectomy. However, the left portal vein (LPV) was narrowed by hepatic cysts in the Spiegel lobe; thus, sufficient left liver regeneration could not be expected after conventional PVE. Laparoscopic unroofing of hepatic cysts, partial liver partitioning, and transileocecal PVE were therefore performed as the first stage of partial transileocecal portal vein embolization with associated liver partition and portal vein ligation for staged hepatectomy (partial TIPE ALPPS). The pressure gradient between the main portal trunk and LPV was 1.5 cm. Two and four weeks after the first stage, the FLR volume increased to 39.0% and 41.5%, respectively; however, the indocyanine green (ICG) retention rate at 15 min and ICG clearance of remnant liver values were 17.8% and 0.047 (lower than the safe criterion ≥ 0.05), respectively. To overcome the slightly insufficient FLR volume, right hemihepatectomy was performed after additional right hepatic vein deprivation (HVD) without any signs of posthepatectomy liver failure. This case illustrates a novel strategy that combines laparoscopic unroofing, partial TIPE ALPPS, and right HVD to achieve functional liver regeneration in cases of LPV stenosis.

Keywords: laparoscopic unroofing, portal vein stenosis, partial TIPE ALPPS, hemihepatectomy, hepatic vein deprivation

1. Introduction

Preoperative portal vein embolization (PVE) before major hepatectomy is a widely adopted method to prevent posthepatectomy liver failure (PHLF) in patients with an insufficient future liver remnant (FLR) volume (*1*). However, if the portal blood flow in the FLR is impaired, adequate liver regeneration cannot be achieved. Therefore, improvement of portal venous inflow may be required before performing PVE.

Herein, we report on a two-stage hepatectomy combined with laparoscopic unroofing, partial transileocecal portal vein embolization with associated liver partition and portal vein ligation for staged hepatectomy (partial TIPE ALPPS), and right hepatic vein deprivation (HVD) before right hemihepatectomy performed in a patient with intrahepatic cholangiocarcinoma associated with left portal vein (LPV) stenosis caused by hepatic cysts.

2. Case presentation

A 76-year-old female presented with an intrahepatic cholangiocarcinoma. Laboratory data showed no elevation of hepatobiliary enzymes, while the tumor marker CA19-9 was markedly elevated (9,557 U/mL). The indocyanine green retention rate at 15 min (ICG-R15) and clearance rate of ICG (ICG-K) were 12.3% and 0.138, respectively, suggesting mild impairment of liver function. The Child-Pugh score was five. Contrast-enhanced CT revealed a 16-mm hypovascular mass in the caudate process of the liver involving the right Glissonean pedicle. Gadolinium-EOB-MRI revealed a distinct hypointense area in the corresponding region during the hepatobiliary phase (Figure 1A). The LPV was markedly narrowed owing to compression by hepatic cysts in the Spiegel portion of the liver (Figure 1B). The estimated FLR volume was 21.9% of the total liver volume, indicating that the FLR volume

did not satisfy the safe criteria for hepatectomy; FLR volume / total liver volume $\times$ ICG-K = (indocyanine green clearance of remnant liver [ICG-Krem]) ≥ 0.05 (2). Right hemihepatectomy after preoperative PVE was planned for resection of the tumor; however, it was considered that the narrow LPV would inhibit sufficient liver regeneration after conventional PVE.

2.1. First-stage of partial TIPE ALPPS

To relieve portal stenosis, laparoscopic unroofing of the hepatic cysts was performed first. The pressure gradient between the main portal trunk and LPV—which disappeared after unroofing—was found to be 1.5

cm H₂O. Subsequently, partial transileocolic PVE with associated liver partition and portal vein ligation for staged hepatectomy (partial TIPE ALPPS) (3,4) was conducted; selective right portal branch embolization was thus performed following laparoscopic partial liver partitioning along the Rex–Cantlie line (Figure 2A). Follow-up CT imaging 2 and 4 weeks after the first stage showed a patent LPV (Figure 2B) and progressive hypertrophy of the left FLR (39.0% and 41.5% of the total liver volume, respectively). However, the ICG-R15, ICG-K, and ICG-Krem values (2) decreased to 17.8%, 0.114, and 0.047, respectively.

To overcome the slightly insufficient FLR volume, a right HVD was performed 43 days after the first stage.

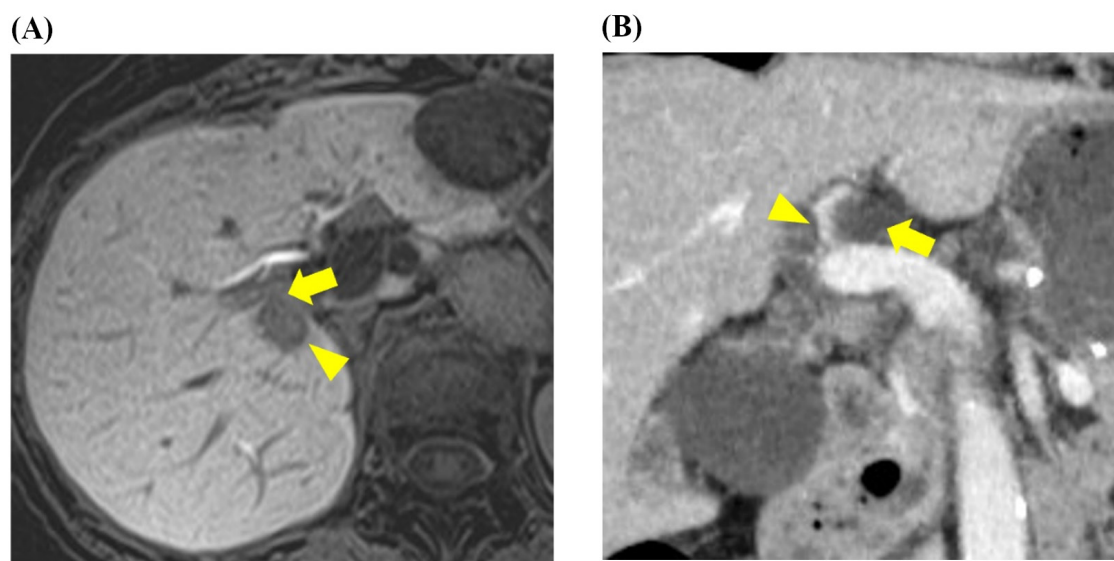


Figure 1. (A) Gadolinium-EOB-MRI image. A 16-mm mass exhibiting a clearly hypointense area in the hepatobiliary phase is observed in the paracaval portion of the liver (yellow arrowhead). The boundary between the mass and the right Glissonean sheath is indistinct, suggesting possible invasion of the mass (yellow arrow). **(B) Dynamic CT (coronal view).** The left portal vein was stenosed (yellow arrowhead) due to compression by hepatic cysts (yellow arrow).

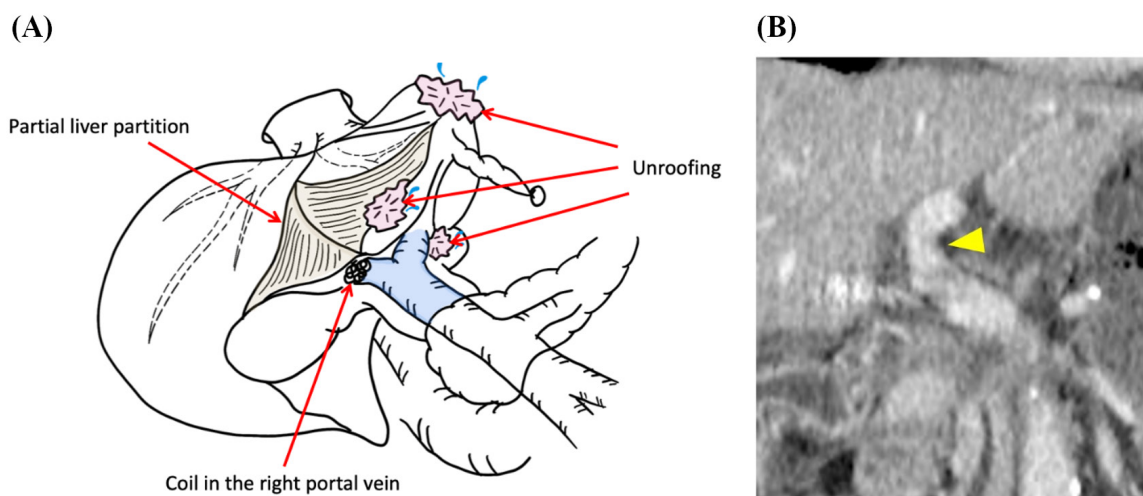


Figure 2. (A) Laparoscopic unroofing. Laparoscopic unroofing was performed for hepatic cysts in the Spiegel lobe, segment 3, and segment 4. The cyst in the Spiegel lobe compressed and narrowed the left portal vein, and laparoscopic partial liver transection was performed along the Rex–Cantlie line. **(B) Dynamic CT (coronal view) obtained 2 weeks after partial TIPE ALPPS.** The stenosis of the left portal vein was relieved (yellow arrowhead).

Two weeks after the right HVD, the ICG-Krem score decreased to 0.038 owing to the decrease in ICG-K value. However, the liver parenchyma appeared fine in the first stage, and functional FLR—as assessed by ^{99m}Tc -galactosyl serum albumin (^{99m}Tc -GSA) scintigraphy (5)—increased from 21.4% to 54.1% between the initial and preoperative states. Therefore, we performed a right hemihepatectomy after obtaining consent from the patient regarding the possibility of developing hepatic failure after major hepatectomy.

2.2. Second-stage of partial TIPE ALPPS; right hemihepatectomy

In the second stage, open right hemihepatectomy was performed along the partial transection plane. The operative time was 289 min, estimated blood loss was 541 mL, and Pringle time was 20 min. The postoperative course was uneventful, with no signs of PHLF. The patient was discharged on postoperative day 11.

At the latest follow-up (7 months after surgery), the patient remained well, with no evidence of liver failure or disease recurrence.

3. Discussion

This is the first report of a surgical strategy combining laparoscopic unroofing, partial TIPE ALPPS, and right HVD to induce hypertrophy of the FLR before right hemihepatectomy in a patient with an impaired LPV due to compression by hepatic cysts. A literature search was conducted using PubMed with the keywords "hepatic cyst", "portal vein compression", "ALPPS", and "hepatic vein deprivation". To the best of our knowledge, no previous reports have described this combined strategy. After the first stage of partial TIPE ALPPS, the LPV was noticeably patent and the FLR volume increased by 19.6% of the total liver volume. However, due to the deterioration of hepatic function indicated by the ICG test, a right HVD was performed, resulting in a remarkable increase in functional FLR volume on ^{99m}Tc -GSA scintigraphy. Right hemihepatectomy was successfully performed without any signs of PHLF.

Preoperative PVE to increase the FLR volume before major hepatectomy was first performed by Makuuchi *et al.* (1) in 1985 and is now widely performed to prevent PHLF. However, 20% of patients who undergo PVE do not undergo hepatectomy, mostly due to disease progression during the waiting period of 3–8 weeks (6). To accelerate hepatic regeneration, Schnitzbauer *et al.* (7) first reported ALPPS in 2012, demonstrating a 60–80% increase in original FLR volume from 7 to 10 days. This new procedure is associated with morbidity and mortality rates of 80% and 9–12%, respectively. Surgical morbidity after the first stage involved congestion or necrosis of the deportalized hemiliver after complete parenchymal transection, and bile leakage from the bilateral wide

hepatic transection planes. Sakamoto *et al.* (3,4) introduced partial TIPE ALPPS to avoid the congestion of the deportalized hemiliver, bile leakage, and adhesion to the hepatoduodenal ligament after the first stage.

In the present case, hypoplasia of the left liver may have been attributed to LPV stenosis secondary to hepatic cysts in the Spiegel portion of the liver. Accordingly, partial TIPE ALPPS was performed in combination with laparoscopic unroofing to relieve LPV stenosis and enhance the hypertrophy of the remnant liver. After laparoscopic unroofing, portal venography showed disappearance of the pressure gradient between the main portal trunk and the LPV. The FLR volume/total liver volume increased from 21.9% to 41.5% 4 weeks after the first stage of partial TIPE ALPPS, without any surgical morbidity.

Nagino *et al.* (8) reported the first case of HVD in 2003. Hwang *et al.* (9) reported the first case series of sequential HVD, stating that this approach effectively promoted liver regeneration by inducing greater hepatic injury than PVE alone. In recent years, several studies have reported the efficacy of HVD in promoting additional growth in FLR volume. In a comparative analysis, Kobayashi *et al.* (10) reported that the combination of HVD and PVE resulted in a significantly higher FLR growth rate than PVE alone (35% vs. 24%; $p = 0.034$). Araki *et al.* (11) found that adding HVD after PVE to patients with insufficient functional FLR volume (12) produced a more substantial improvement in functional than volumetric FLR volume after HVD. In the present case, the right HVE performed after partial TIPE ALPPS did not result in a further volumetric increase in the FLR; however, ^{99m}Tc -GSA scintigraphy demonstrated an improvement in FLR function. There are few reports on the clinical value of ^{99m}Tc -GSA scintigraphy for assessing remnant liver function, and its usefulness remains uncertain (13,14). Miki *et al.* (15) reported that assessment of remnant liver clearance by ^{99m}Tc -GSA scintigraphy in 70 patients undergoing major hepatectomy was more accurate than CT volumetry for predicting PHLF.

In the present case, the ICG-R15 value deteriorated after PVE associated with the laparoscopic unroofing of the hepatic cysts and partial liver partitioning. Yokoyama *et al.* (16) showed no changes in ICG values before and after PVE in 205 patients with biliary cancer. Yamashita *et al.* (6) obtained similar results in 319 patients who underwent PVE for resection of various malignancies. By contrast, Chan *et al.* (17) demonstrated a significant increase in ICG-R15 value from 8.8% to 10.2% after ALPPS ($p = 0.024$). As the ICG-R15 depends on hepatic blood flow, hepatocellular uptake, and biliary excretion, the increase in the ICG-R15 may be due to the improvement of the LPV stenosis and rapid hemodynamic changes in portal and arterial flows following the first stage of partial TIPE ALPPS.

Since the introduction of PVE, various measures have been developed to prevent PHLF after major hepatectomy (18). None of the single measures would be sufficient to

overcome PHLF, and we have entered the phase where using several methods in combination is crucial. In that sense, the present case report using partial TIPE ALPPS and HVD with improvement of portal vein compression may represent a groundbreaking approach.

In conclusion, LPV stenosis caused by hepatic cysts was successfully managed by unroofing; this improved portal flow, allowing for subsequent partial TIPE ALPPS and right HVD, ultimately leading to a second-stage right hemihepatectomy without PHLF.

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