



Three Possible Variations in Ex Vivo Hepatectomy: Achieving R0 Resection by Auto-transplantation

Maria R. Baimas-George¹ · David M. Levi² · Dionisios Vrochides¹

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Abstract

The collaboration of hepatopancreaticobiliary with transplant surgery expands technical options and opportunity for potentially curative resection in traditionally inoperable cases. We identified and describe three different types of ex vivo hepatic resections that include (1) explantation with formal hepatectomy, (2) explantation with re-implantation of the whole liver after vascular reconstruction, and (3) explantation with formal hepatectomy after future liver remnant volume augmentation.

Keywords Ex vivo · Hepatectomy · Transplant · Surgical oncology · Hepatopancreaticobiliary · Liver resection · Inferior vena cava resection

The collaboration of hepatopancreaticobiliary with transplant surgery expands technical options and opportunity for potentially curative resection in traditionally inoperable cases. For instance, venovenous bypass with hypothermic hepatic preservation allows for ex vivo resection of malignancies encasing vasculature at the hepatocaval junction or involving the inferior vena cava (IVC) that historically were deemed inoperable. This technique improves margin status by suspending hepatic inflow and outflow for explantation, allowing optimal resection on the back table. Even though these are high mortality procedures, there have been successful case series reported, yielding acceptable oncologic outcomes.^{1, 2} Each of these cases is unique and requires operative ingenuity with its own specific technical solution. From our institution, we identified three different types of ex vivo hepatic resections that represent a merger of transplant and surgical oncology. These R0 operations include (1) explantation with formal hepatectomy;

(2) explantation with re-implantation of the whole liver after vascular reconstruction; and (3) explantation with formal hepatectomy after future liver remnant volume augmentation.

Case 1: Ex Vivo Hepatic Resection with Re-implantation of Liver Remnant Without Hepatic Augmentation

An otherwise healthy 41-year-old woman with Lynch syndrome presented with a metastatic hepatic lesion secondary to rectosigmoid colon cancer. The lesion, measuring 11.3 by 7.9 cm, was located in the caudate lobe and involved all hepatic veins and IVC confluence (Fig. 1a). The patient underwent systemic neoadjuvant chemotherapy with no improvement. After adjustment to pembrolizumab, a programmed cell death-1 (PD-1) checkpoint inhibitor, there was a significant decrease in the central hepatic lesion; however, it still involved a major portion of the IVC and hepatic segment 1. An R0 resection was performed with ex vivo left hepatectomy, retrohepatic IVC replacement, and auto-transplantation of the residual liver. Using venovenous bypass, the liver was removed en bloc with the IVC. The hepatectomy was performed at the back table and the IVC was replaced with a 22-mm PTFE graft to which the right hepatic vein was implanted. The arterial and portal anastomoses were performed in an end-to-end fashion and a Roux-en-Y hepaticojejunostomy was created for biliary reconstruction (Fig. 2a). Of note, the pathology demonstrated a complete pathological response to pembrolizumab with no evidence of active

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✉ Dionisios Vrochides
dionisios.vrochides@atriumhealth.org

¹ Division of Hepatobiliary and Pancreatic Surgery, Carolinas Medical Center, Atrium Health, 1025 Morehead Medical Dr., Suite 600, Charlotte, NC 28204, USA

² Division of Transplant Surgery, Carolinas Medical Center, Atrium Health, 1025 Morehead Medical Dr., Suite 600, Charlotte, NC 28204, USA

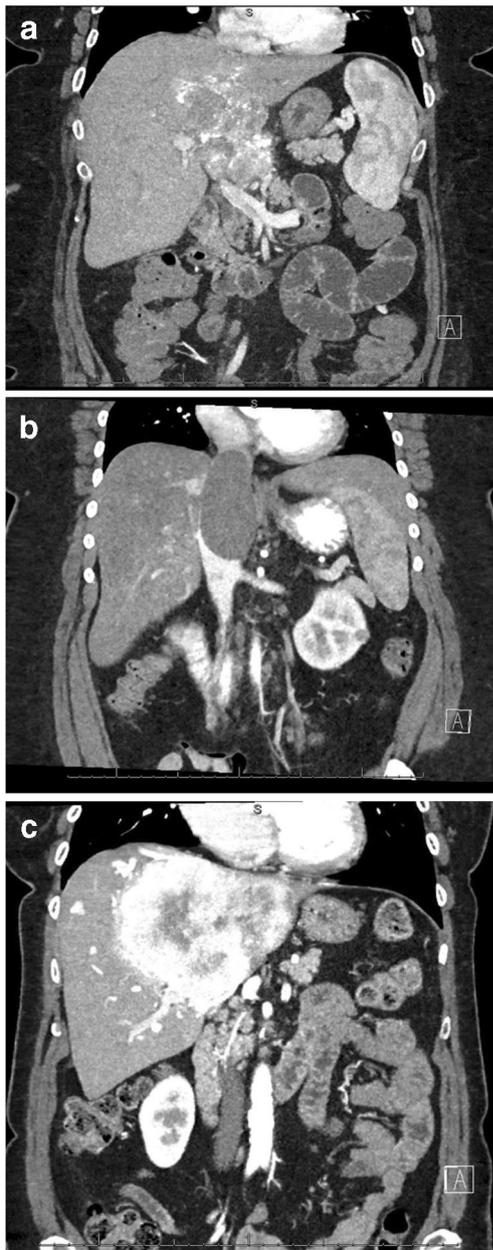


Fig. 1 Preoperative cross-sectional imaging. **a** Metastatic hepatic lesion involving the caudate lobe, all hepatic veins, and the IVC confluence. **b** Smooth muscle sarcoma involving the retrohepatic IVC. **c** Intrahepatic cholangiocarcinoma involving the takeoff of the right anterior portal pedicle but no interface with the right posterior portal pedicle

disease. The patient had no evidence of recurrence at 5-month follow-up.

Case 2: Ex Vivo Hepatic Resection with Re-implantation of the Entire Liver

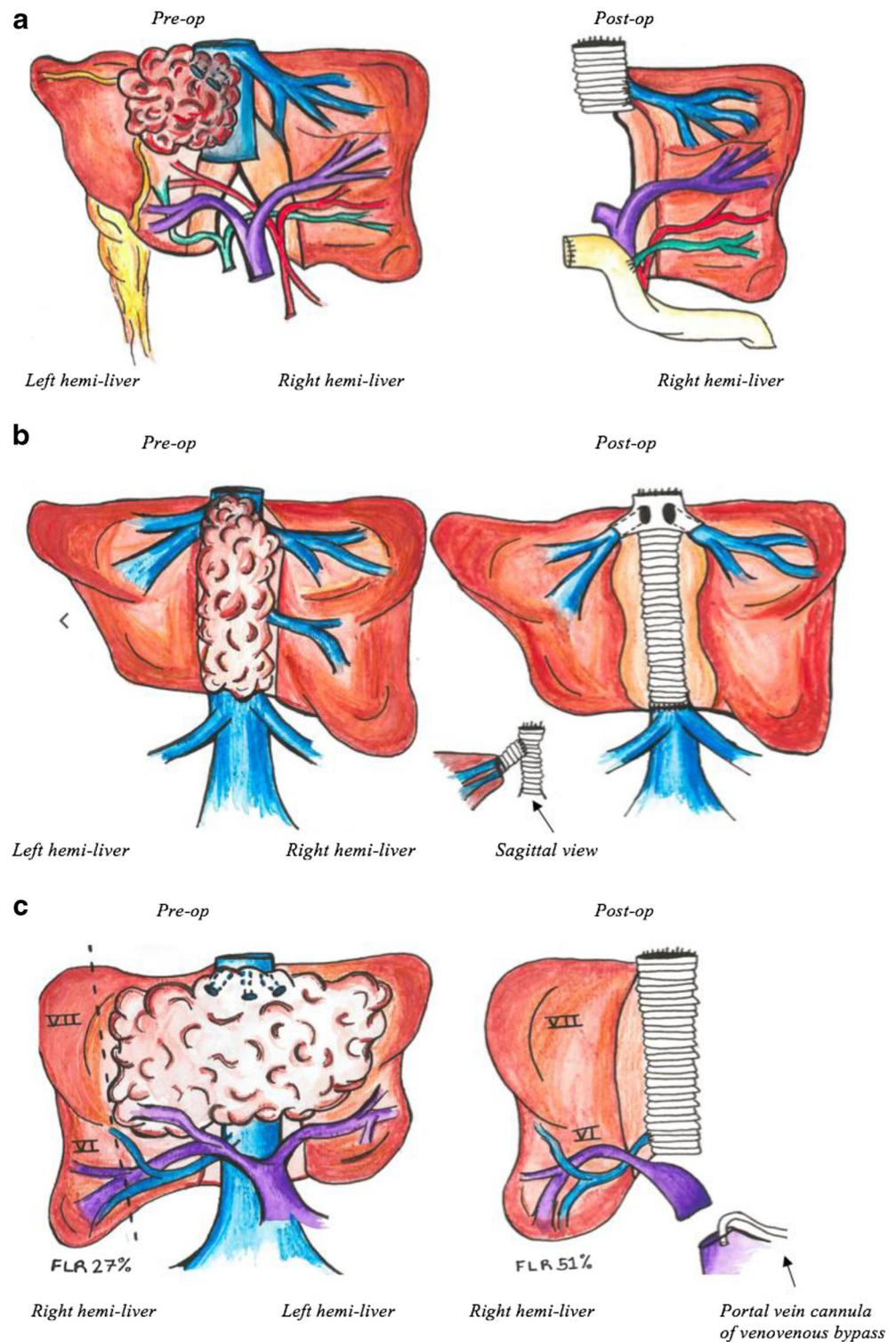
A 36-year-old woman with diabetes, hypertension, and hyperthyroidism presented with an 8.8-cm enhancing mass within the retrohepatic IVC with malignant involvement of all three

hepatic veins' ostia (Fig. 1b). The diagnosis was smooth muscle sarcoma with no evidence of metastatic disease. The patient's potentially only curative treatment was R0 resection. In the operating room, the mass was palpable in the suprahepatic IVC but did not violate the pericardium. Venovenous bypass was initiated and the liver with the suprahepatic and infrahepatic IVC was explanted. The tumor extended along the entire course of the retrohepatic IVC, adherent to the posterior wall. The retrohepatic IVC was fully resected including an intraparenchymal portion (up to 5 mm) of the right hepatic vein with the common channel of the middle and left hepatic veins, until all hepatic vein margins were negative. The hepatic vein outflow was reconstructed utilizing a 24-mm Gelweave graft (blanket). This was anastomosed in a piggy-back fashion to the anterior wall of the reconstituted IVC with a 22-mm PTFE graft. Arterial and biliary reconstruction was performed in an end-to-end fashion (Fig. 2b). The final pathologic diagnosis was leiomyosarcoma with negative margins and lymph nodes, and the patient had no evidence of recurrence at 15-month follow-up.

Case 3: Ex Vivo Hepatic Resection with Re-implantation of Liver Remnant After Augmentation

A 73-year-old woman presented with an intrahepatic centrally located cholangiocarcinoma without history of liver dysfunction (Fig. 1c). The mass, measuring 12.7 by 8.8 cm, involved all hepatic segments except 6 and 7, and infiltrated the IVC, all three hepatic veins, and the right anterior portal pedicle. The patient underwent systemic chemotherapy and trans-arterial chemoembolization with some improvement in tumor burden and no evidence of metastatic disease. Operative planning centered around preserving an uninvolved right accessory hepatic vein and posterior branch of the right portal pedicle. Explantation with hepatectomy alone would not be sufficient as the patient's future liver remnant (FLR) was 27% and FLR of > 50% was presumably required due to prior chemotherapy and future cold perfusion. Portal vein embolization was attempted but not possible due to compromise of the posterior portal pedicle; therefore, a rescue associated liver partition and portal vein ligation for staged hepatectomy (ALPPS) was performed. The hypertrophic stimulus of the ligated left portal vein and parenchymal transection resulted in rapid hypertrophy and an increase in FLR from 27 to 51%. Stage two of the operation was completed after 11 days with ex vivo hepatic resection, IVC reconstruction, and auto-transplantation of segments 6 and 7. More specifically, intraoperatively, the right posterior section was found to be adequately regenerated and the liver was removed en bloc with the retrohepatic IVC. The left trisectionectomy and IVC resection were completed with preservation of segments 6 and 7, the right posterior hepatic

Fig. 2 Artistic renditions of the preoperative and postoperative anatomy. **a** Ex vivo hepatic resection with re-implantation of liver remnant without hepatic augmentation. **b** Ex vivo hepatic resection with re-implantation of entire liver. **c** Ex vivo hepatic resection with re-implantation of liver remnant after augmentation



artery, right accessory hepatic vein (Makuuchi vein) on an IVC patch, and posterior branch of the right portal pedicle. The IVC was replaced with a 24-mm PTFE graft, the autograft was re-implanted, and the vascular anastomoses were performed in an end-to-end fashion (Fig. 2c). The patient had no evidence of disease recurrence at 12-month follow-up.

Of note, in each procedure, the livers were flushed with 2 l of University of Wisconsin (UW) solution (Viaspan, DuPont Pharma, Wilmington, DE, USA) via the portal vein and hepatic artery and placed in ice bath. The cold ischemia time ranged from 110 to 165 min and the warm ischemia time varied from 45 to 70 min.

Transplant oncology may be defined as the combination of surgical oncology principles with transplant techniques in order to achieve optimal resectional outcomes, i.e., an R0 resection. This approach was introduced with the application of venovenous bypass and explantation/re-implantation for technically challenging hepatic disease.³ Besides many reports for treatment of malignancies, a recent case series demonstrated considerable potential in conventionally unresectable echinococcal disease as well.^{1, 2} As exemplified in this single-center experience, transplant oncologic techniques are not one single type of procedure. They can incorporate explantation with or without hepatectomy, re-implantation, caval graft reconstruction, and liver remnant augmentation (PVE or even ALPPS). It offers additional potential in achieving technical resectability in patients who conventionally have no operative options, rendering the future of once technically unresectable tumors into opportunities for R0 resection. As such, the definition of unresectability should be an oncologic, not a technical, concept.

The illustrations (Fig. 2a–c) were done by the author, Maria Baimas-George.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflicts of interest.

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