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New Techniques

Challenges in retrohepatic inferior vena cava reconstruction: The neocava technique

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The development of innovative surgical techniques has been a constant and fundamental aspect in liver transplantation (LT) to address chronic organ shortage. Domino liver transplantation (DLT), initially performed by Furtado et al. in Lisbon in 1995, is an innovative technique in which a liver from a patient with a metabolic disorder is transplanted into a recipient with end-stage liver disease [1].

Simultaneously, advancements in liver tumor resectability have progressed to reduce the need for allograft LT, thereby circumventing issues related to organ shortage and complications of immunosuppression. *Ex-situ* liver resection and autotransplantation (ELRA), an extreme liver surgery technique embodies this principle. First performed in 1988 in Hannover by Pichlmayr et al. [2], ELRA involves performing tumor excision on the back-table following a total hepatectomy, after which the liver is reimplanted. This technique enables the achievement of an R0 surgical margin, which is often unattainable with conventional approaches. The primary indications for ELRA include tumors invading the hepatic hilum or retrohepatic inferior vena cava (IVC), where resection of these major vessels is required. These techniques are now well-established and indicated in selected patients, offering advantages such as shorter waiting listing time, reduced mortality rates, and complete liver tumor clearance.

Historically, in the classic LT technique, liver outflow is restored through recipient's IVC replacement under cross clamping, a technique that often results in hemodynamic instability due to insufficient cardiac venous return, which can be circumvented by the establishment of a temporary veno-venous bypass [3]. Nowadays, the piggyback technique has largely replaced the classical approach, as it can be performed without necessity of IVC cross clamping, thereby avoiding the preload drop [4]. Two variations of this technique are widely used: (1) in standard piggyback (SPB), graft supra-hepatic venocaval cuff is anastomosed end-to-side to the recipient's enlarged hepatic veins cuff (corresponding to the initial definition of piggyback technique) [4]; (2) in the modified piggyback (MPB), the liver outflow is ensured via a side-to-side anastomosis between the donor and recipient IVCs under lateral clamping (also known as side-to-side cavo-cavoplasty) [5]. This outflow restoration technique is now standardized for nearly 30 years in our institution [6].

A recent meta-analysis showed that both SPB and MPB offer comparable postoperative outcomes and are associated with shorter operative time, as well as reduced need for red blood cells and fresh frozen plasma transfusions compared to the classical technique [7].

In DLT, liver procurement spares the domino donor's retrohepatic IVC (living donor). In ELRA for retrohepatic IVC invasion (IVC-ELRA), the IVC is resected on the back-table after total hepatectomy due to tumor invasion. During this procedure, the native IVC is reconstructed with tubulized autologous peritoneum, biobank homologous venous grafts, or Gore-Tex before liver reimplantation. In all cases, the stump of the common trunk and right hepatic vein is short, making SPB anastomosis technically challenging, potentially leading to hepatic vein outflow obstruction (HVOO), therefore associated with a risk of liver congestion, hemorrhage, and ascites. All these conditions lead to graft failure and even fatal for the patient. In this context, various IVC suprahepatic tripod reconstructions have been described to facilitate SPB anastomosis [8–10].

The aim of this work is to provide a detailed description of a simplified retrohepatic IVC surgical reconstruction technique. This allows a hepatic outflow restoration with standard side-to-side cavo-cavoplasty (MPB) following the IVC-ELRA and DLT. This technique was based on our center extensive experience about tubulized IVC reconstruction using cryopreserved venous allograft or autologous peritoneum in multivisceral resections [11,12]. According to this experience, such tubulized IVC reconstruction is considered as a well-settled and standardized procedure. Both patients were aware of the different possibilities for IVC reconstruction and consented for the surgery.

In case 1 (DLT procedure), LT indication was decompensated cirrhosis (primary sclerosing cholangitis) in a 68-year-old male, complicated by encephalopathy, refractory pruritus and ascites. The graft was issued from a 53-year-old female affected by familial amyloidosis complicated by end-stage kidney failure. There were no other organs affected by amyloidosis nor portal hypertension. Therefore, DLT indication was retained. Cold ischemia time (CIT)

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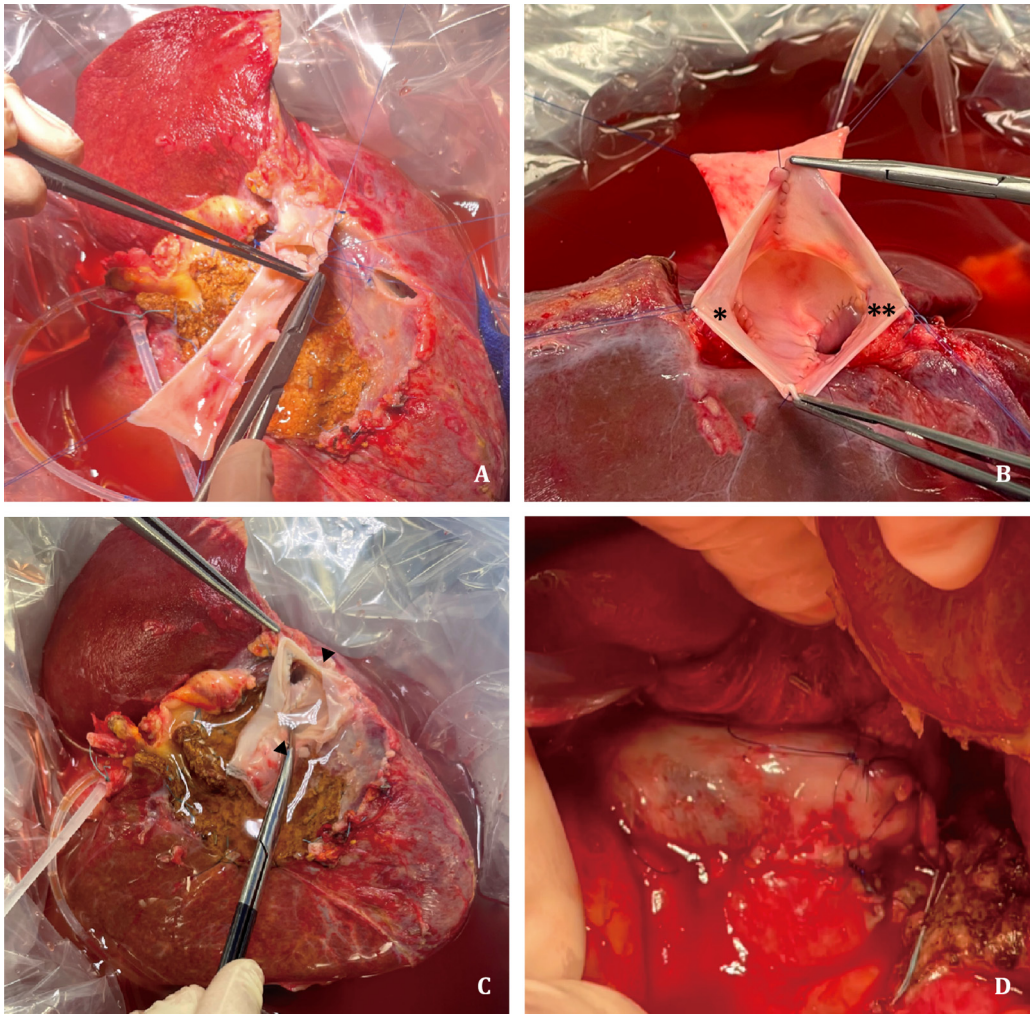

Fig. 1. Liver outflow reconstruction. **A:** Right hepatic vein anastomosis to neocava in an end-to-side fashion with longitudinal incision on right neocava lateral face. **B:** Cranial inner view within neocava: right hepatic vein anastomosis *, common trunk anastomosis **. **C:** A 5 cm-long longitudinal incision on posterior wall of neocava to prepare MPB anastomosis. **D:** Post-implantation view: MPB anastomosis. MPB: modified piggyback.

and warm ischemia time (WIT) were 236 and 36 minutes, respectively, with 700 mL total blood loss (no transfusion required). WIT consisted in 3 minutes of donor's functional WIT and 33 minutes of receiver's WIT (side-to-side cavo-cavoplasty and portal vein anastomosis).

In case 2, an 84-year-old female in excellent general condition [Eastern Cooperative Oncology Group (ECOG) score 0] was diagnosed with primary IVC leiomyosarcoma located at hepato-caval confluence. The tumor extended intrahepatically posteriorly up to the confluence of the three hepatic veins and exhibited a 5-cm extension into the right atrium. This thrombus was causing rapidly progressing dyspnea due to impaired cardiac venous return. Without surgical intervention, this thrombus would have led to terminal cardiac failure and pulmonary embolism in a short time frame. Surgical treatment was discussed with the patient and within a multidisciplinary meeting, who unanimously approved the procedure: IVC-ELRA indication under sterno-laparotomy was decided. We performed atriotomy with thrombus extraction and partial right atrium resection under extra-corporeal circulation (230 minutes) [13]. CIT and WIT were 220 and 26 minutes, respectively. The estimated intraoperative blood loss was 3 L, essentially related to cardiac surgery. We transfused 3 units of packed red blood cells. WIT consisted in 6 minutes of donor's functional WIT and 20 minutes of receiver's WIT (side-to-side cavo-cavoplasty and portal vein anastomosis) [13].

In both cases, homologous venous iliaco-caval graft (either cadaveric or cryopreserved) was used for retrohepatic IVC reconstruction. The iliac limbs of the graft were opened medially and tighted together with running sutures along the anterior and posterior walls to create a large tubular vein, which served as the neocava.

On the back-table, the cavo-hepatic confluence was reconstructed using the distal iliac segments of the tube, chosen for its wider caliber, to form the new cavo-hepatic confluence. The common trunk of the hepatic veins was anastomosed to the left lateral aspect of the neocava through a transverse incision, while the right hepatic vein was attached to the right lateral side of the neocava via a longitudinal incision. This configuration was designed to optimize hepatic venous outflow. The superior and inferior ends of the neocava were then closed with a continuous Prolene 6/0 suture (Fig. 1). To ensure vascular integrity, the neocaval vein's blood-tightness was tested on the back-table. Additionally, a 5-cm incision was made slightly lateral to the ilio-iliac suture on the posterior wall.

In case 1, postoperative course was uneventful, and a systematic CT scan was performed on postoperative day 7 to assess cavo-caval

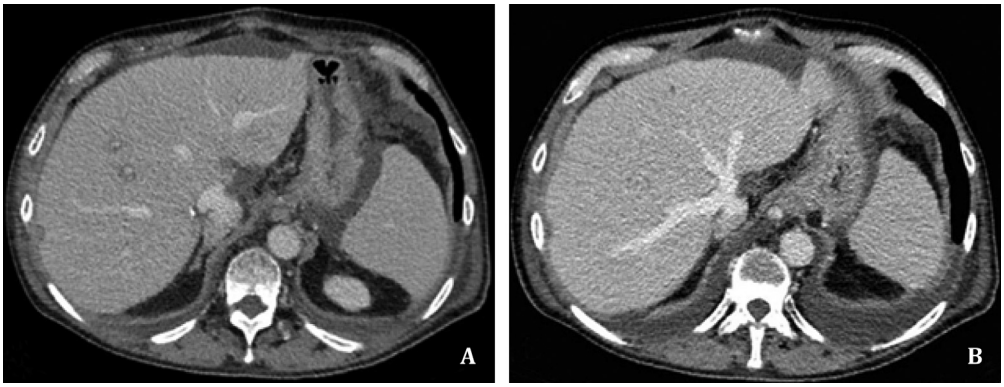

Fig. 2. Computed tomography scan at postoperative day 7. **A:** Side-to-side cavo-cavoplasty patency. **B:** Patency of the three hepatic veins.

anastomosis patency (Fig. 2). Patient was discharged 12 days after LT with normal liver function.

In case 2, postoperative course was marked by an early-stage biliary leak, requiring surgical exploration. Further postoperative course was uneventful allowing hospital discharge after 15 days. Nevertheless, patient opted for a transition through rehabilitation before returning home. An additional 17 days were required to secure a spot at the rehabilitation facility. Finally, patient was discharged on postoperative day 32 and was able to go back home 47 days after surgery.

Both patients are in good condition 18 months after surgery, with a patent anastomosis, a normal liver function and no HVOO-related complications.

By providing a new method to address challenges of retrohepatic IVC reconstruction, we aim to improve graft and patient outcomes by allowing standardized MPB anastomosis. Compared to classical technique, it offers the possibility to perform outflow reconstruction under partial lateral IVC clamping, preserving sufficient preload and thereby avoiding hemodynamic instability and the necessity of a veno-venous bypass. Compared to SPB anastomosis, the neocava technique offers the advantage to easily perform an MPB anastomosis in a standardized way, allowing a short WIT and reducing the risk of HVOO related to the short hepatic vein cuffs.

Hepato-caval confluence reconstruction is challenging in both DLT and IVC-ELRA, particularly to perform SPB due to the short hepatic vein cuffs, which increases the risk of HVOO, or classical implantation technique, which increases the risk of unstable patient during surgery. We present a novel approach that involves creating a neocava with a simplified cavo-hepatic confluence reconstruction at a lower cost, without the need for IVC cross-clamping. In our experience, this straightforward technique allows for an MPB technique to restore liver outflow, with favorable early and long-term outcomes, avoiding outflow complications. This method may serve as a valuable tool to expand the range of outflow reconstruction options in these complex and rare cases.

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CRediT authorship contribution statement

Maximilien Roumain: Conceptualization, Formal analysis, Writing – original draft. **Maxime Foguenne:** Conceptualization, Formal analysis, Writing – original draft. **Lancelot Marique:** Conceptualization, Formal analysis, Writing – review & editing. **Olga Ciccarelli:** Writing – review & editing. **Eliano Bonaccorsi-Riani:** Writing – review & editing. **Thomas Bidoul:** Writing – review & editing. **Laurent Coubeau:** Investigation, Supervision, Validation, Writing – review & editing.

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Ethical approval

This study was approved by our local Ethics Committee.

Competing interest

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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