Two-Stage Recipient Hepatectomy and Left Liver Transplantation to Minimize Risks in Adult-to-Adult Living Donor Liver Transplantation: New Concepts

TO THE EDITOR:

The combination of a 2-stage total hepatectomy and partial liver transplantation (LT) for secondary unresectable liver-only malignancies is producing a great quantity of literature. In the first stage, the partial hepatectomy leaves a deportalized right liver while a left graft LT is performed. The second stage is scheduled after enough liver regeneration has occurred, and it consists of removal of the residual liver.

These strategies alleviate the organ shortage in a moment when novel indications are increasing and while deceased donor transplantation is stagnating despite the adoption of marginal candidate donations and organ splitting. Additionally, a timely total hepatectomy is crucial in oncological surgery, though it hardly meets the constraints of the waiting list. The introduction of living donor liver transplantation (LDLT) decades ago raised great expectations in this context.

Unfortunately, after the initial interest, most Western centers have progressively disregarded this tricky procedure. We have already reported our experience with standard total hepatectomy and LDLT (64 patients), and we showed that 1 in 4 recipients experienced small-for-size syndrome, 1 in 6 had arterial complications, and 1 in 7 resulted in postoperative death.[1] In contrast, a 2-stage approach appears to be a true game changer for the technical hurdles of LDLT.[2,3] On the basis of these assumptions, we recently performed our first case of a 2-stage total hepatectomy coupled with a left liver LDLT, the details of which are extensively reported in Tables 1–3 and the Supporting Materials. With this communication, we report our technical strategy and give a general insight into this topic.

Abbreviations: BMI, body mass index; CT, computed tomography; ELH, extended left hepatectomy; GRWR, graft-to-recipient body weight ratio; ICU, intensive care unit; LDLT, living donor liver transplantation; LH, left hepatectomy; LOS, length of hospital stay; LT, liver transplantation; MRI, magnetic resonance imaging.

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Patient and Method

THE DONOR PROCEDURE

Our experience and standardized surgical technique in adult-to-pediatric LDLT emphasizes that a left donor hepatectomy is a highly reliable procedure (Table 1).[4] The key of adult-to-pediatric LDLT is risk minimization for the donors and recipients because a left hepatectomy (LH) is traditionally associated with fewer and less severe postoperative complications[1,5] and because small patients are well-suited to small grafts. Comparably, adult recipients with no portal hypertension may settle for tiny left liver grafts.[6] Through an upper midline incision, we carried out an open left hepatic resection with the procurement of the middle hepatic vein.

TABLE 1. Clinical Details of the First Case

Characteristics	Details
Preoperative data	
Donor	
Age, years	48
Weight, kg	67
Height, cm	155
BMI, kg/m^2	28
Portal anatomy	Type 2 (trifurcation)
Arterial anatomy	Modal
Biliary anatomy	Modal
Graft volume, mL*	290
Graft weight, g†	261
Recipient	
Age, years	55
Weight, kg	57
Height, cm	162
BMI, kg/m^2	22
Operative data	
Donor procedure	
Procedure	Open LH (segments 2, 3, and 4)
Operating time, minutes	310
Blood loss, mL	160
Graft weight, g	236
ICU, hours	24
LOS, days	14
Dindo-Clavien classification	1

*The volume estimation is based on MRI and CT scan imaging that was obtained through the software Vitrea (Vital Images, Inc., Minnetonka, MN).
†Weight estimation is based on the Vitrea calculation minus 10%.

TABLE 2. Details of the Recipient Procedure

	Details
First stage	
Procedure	Open left trisectionectomy (segments 1, 2, 3, 4, 5, and 8) and LT
Operating time, minutes	
Partial hepatectomy	390
Implantation	230
Blood loss, mL	450
Resected liver weight, g	895
Ischemia time, minutes	
Cold	159
Warm	38
Hemodynamic data	
Native portal flow, mL/minutes	1100
Native portal pressure, mm Hg	8
Graft total portal flow, mL/minutes	475
Graft-indexed portal flow, mL/minutes/100 g of graft weight	210
Graft portal pressure, mm Hg	28
Portal inflow modulation (splenic artery ligation)	Yes
ICU, hours	36
LOS, days	15
Dindo-Clavien classification	1
Second stage	
Procedure	Laparoscopic right posterior sectionectomy (segments 6 and 7)
Operating time, minutes	177
Blood loss, mL	100
Specimen weight, g	485
ICU, hours	24
LOS, days	6
Dindo-Clavien classification	1

THE RECIPIENT PROCEDURE

First Stage

The first step was the partial removal of the native metastatic liver (Fig. 1; Table 2). We carefully discussed the surgical strategy for partial hepatectomy in advance on the basis of the preoperative imaging. The primary aim was to avoid having the transection line pass through lesions and expose the tumor. We thus adapted from a standard LH to an extended left hepatectomy (ELH). In the first case, the reference plane was the Cantlie line, and the parenchymotomy was carried out after a standard extra-Glissonean hilar dissection. In the second case, the section line was identified after the right anterior hilar dissection by intra-arterial injection of indocyanine green and intraoperative fluoroscopy. After parenchymotomy, the middle and left hepatic veins were dissected well into the liver to obtain a nice cuff for the hepatic vein anastomosis during graft implantation. We then divided the vascular pedicles, removed the specimen, and reinforced the remnant biliary stump with a running suture. We deportalized the remnant right liver and resected the main portal convergence. In essence, the surgery should adhere to sound anatomical criteria to curb the risk of biliary leakage. The need for a flawless surgery was driven by the risk of a cumulative effect of technical mistakes and of possible postoperative complications.

The second step of the first stage was graft implantation. We started by anatomically anastomosing the left and middle hepatic vein confluence of the donor and the recipient, while the graft was cold rinsed and

TABLE 3. Follow-up Posttransplant Data

	Day 0	Day 10	Day 18	Day 40	Day 90	Day 180
GRWR, %	0.41	0.80	0.91	—‡	1.52	1.44
Graft volume, mL	260	449*	577*	—‡	963*	918*
Graft weight, g	236	404†	519†	—‡	867†	826†
Recurrence		No	No	No	No	No

*The volume estimation is based on MRI and CT scan imaging that was obtained through the software Vitrea (Vital Images, Inc.).
†Weight estimation is based on the Vitrea calculation minus 10%.
‡FDG-Pet excluded recurrence without liver volume calculation.

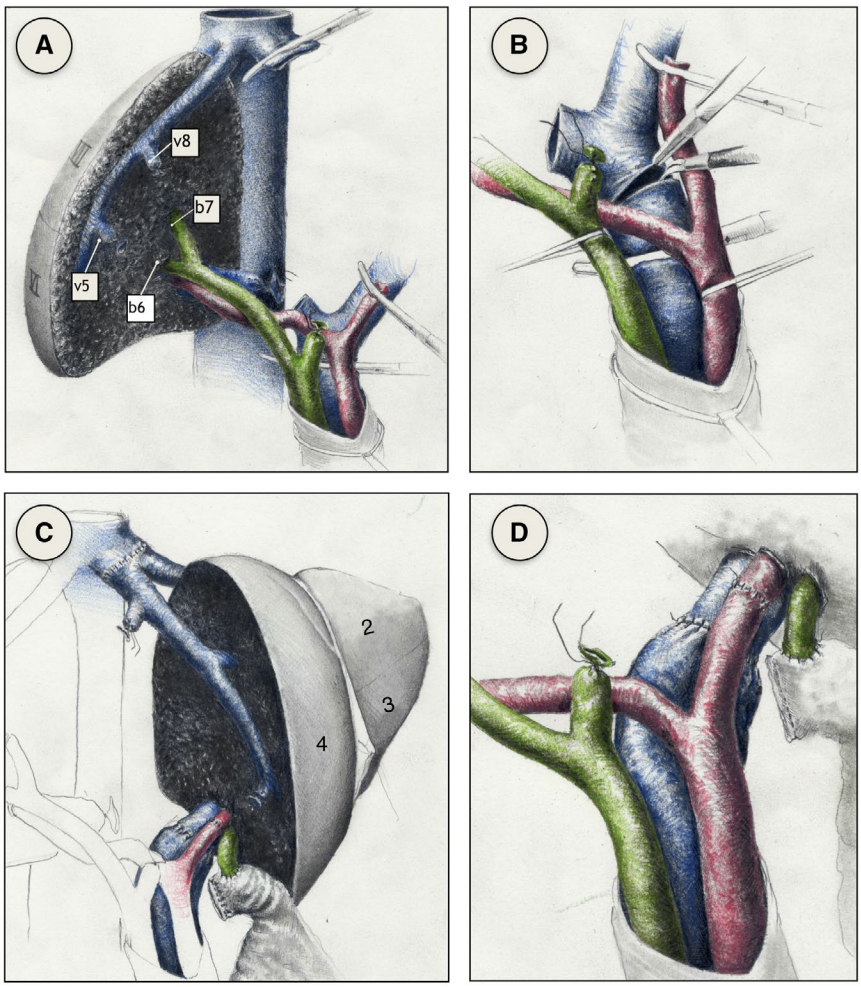

FIG. 1. The first stage of the recipient procedure. (A) ELH in case of a central tumor. (B) Early resection of the main portal convergence with deportalization of the remnant posterior sector. (C) Graft (segments 2, 3, and 4) orthotopic implantation. (D) Anastomosis of the recipient's portal trunk with donor's left portal vein. Venous drainage stumps of segment 5 and 8 into the right hepatic vein are labeled v5 and v8. Biliary branches of segment 6 and 7 are labeled b6 and b7.

wrapped in gauze soaked in cold saline. Next, we anastomosed the recipient portal trunk and the donor left portal vein. Then, we arterialized the graft by anastomosing the donor and recipient left hepatic arteries. We checked graft inflow through transit time flow measurement, and we calculated the intraparenchymal

resistance with an echo-color Doppler ultrasound scan after 30-90 minutes from unclamping to allow for the arterioportal buffer response. We proceeded with graft inflow modulation if the portal flow exceeded 200 mL/minute/100 g of graft weight.[7]

First, by means of a suprapancreatic ultrasound–guided approach, we found and ligated the splenic artery at its origin by placing a Hem-o-lock (Weck Closure Systems, Research Triangle Park, NC) without severing the arterial pedicle. The flow rate was double-checked, and if the portal flow still exceeded the threshold, a partial portocaval shunt was placed. Then, we prepared the remnant native liver for the second stage, which was the completion of the hepatectomy. We placed one silicone vessel loop around the right arteriobiliary pedicle and one around the right hepatic vein. Then, we ligated and severed all accessory hepatic veins so that the inferior vena cava was fully released from the liver. Next, we slipped a large silicone sheath to the right side of the inferior vena cava (IVC), dorsolateral to the liver and against the liver cut surface, to encase the remnant. Lastly, biliary drainage of the graft was restored by hepaticojejunostomy. We cut the jejunum 40 cm from a ligament of Treitz, and we brought the distal end, the future biliopancreatic limb, into the supramesocolic area in a transmesocolic approach. We anastomosed the proximal end to the Roux limb 70 cm away from the future hepaticojejunostomy. We then anastomosed the biliary duct to the bowel in an end-to-side fashion with single-layer separated stitches. We placed an internal biliary stent on a case-by-case basis based on the quality and diameter of the biliary anastomosis. The hepaticojejunostomy was preferred to set the delicate graft biliary tract free from the native one, which has to be manipulated a second time later on. The patient was aware of the significant risk of biliary complications, which occur in 1 out of 3 liver recipients and which, in the setting of adult-to-adult LDLT, occur even more frequently because of the anastomosis between a biliary side branch and a jejunal loop. Before abdominal wall closure, we restored the continuity of the falciform ligament to avoid graft tilting and to keep the cut surfaces of the remnant and of the graft well separated. This expedited the subsequent residual native liver extraction by decreasing interhepatic adhesions.

Second Stage

For the second stage of the recipient procedure, we planned volumetric imaging a fortnight after the first operation (Fig. 2). Accordingly, we completed the native liver resection with a laparoscopic right posterior. We accessed the abdominal cavity using the open laparoscopic technique, starting from the inframesocolic compartment to take advantage of the expected absence of adhesions. We progressively cleaved the native liver remnant, by hydrodissection, until we found the previously encircled arteriobiliary and hepatic pedicles. We then divided the 2 vascular pedicles using an Endo-GIA (Medtronic, Dublin, Ireland) type stapling system. We inserted an extraction bag in the abdomen, and we put the liver inside. Lastly, we performed a Pfannenstiel incision, and we retrieved the organ. The second stage, as a laparoscopic procedure, carries a risk of conversion to open surgery, though the amount of risk intuitively appears to be lower than in a standard right hepatectomy. If needed, a conversion can easily be done by resuming the incision of the first procedure. Follow-up data are shown in Table 3.

Discussion

A 2-stage total hepatectomy coupled with LT is a promising technique in liver oncology, but the reported experience is still sparse. We wish to draw attention to 6 specific issues in this literature.

First, all articles concentrate on colorectal cancer liver metastases.[2,3,8] Nonetheless, the concept can be extended to neuroendocrine tumors and hepatocarcinoma in patients without significant portal hypertension and with a favorable liver anatomy.

Second, most literature reports triple- and quadruple-immunosuppressive regimens. Conversely, a minimized immunosuppression with tacrolimus monotherapy (trough levels, 4-6 ng/mL) and without induction is key for oncological LT recipients.[1]

Third, partial LT is reportedly performed with left lateral sectors (segments 2-3) from deceased or living donors.[2,3] However, the preservation of a vascular pedicle that can be anastomosed requires the division of segment 4 vessels so that segment 4 is completely devascularized and bound to atrophy. Sensibly, the donor procedure should entail a proper LH (segments 2-4) because segment 4 in the donor is useless, whereas in the recipient, it adds precious mass and impacts the need for graft inflow modulation.[7]

Fourth, in the first stage of the recipient procedure, hepatectomy can be customized from a standard LH to an ELH. The aim is to avoid having the section plane pass through metastases and to respect the anatomy

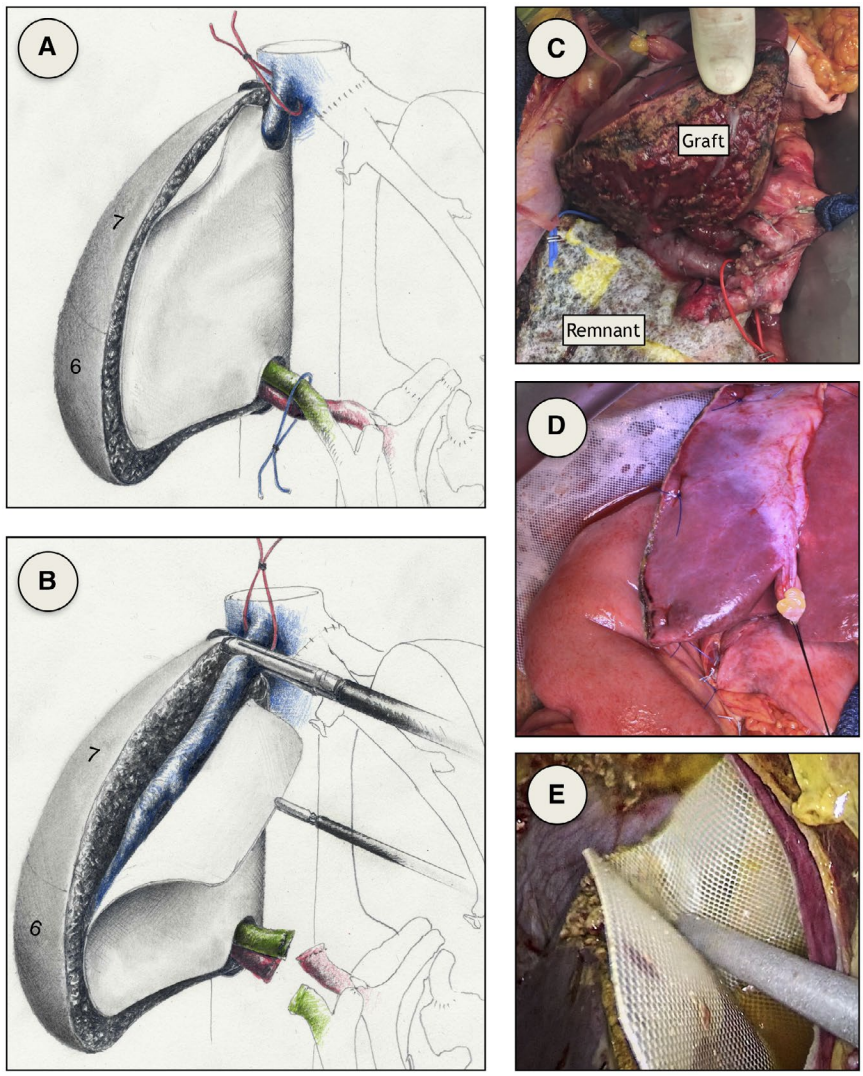

FIG. 2. The second stage of the recipient procedure: (A, B) illustrations and (C-E) pictures. (A, C) The native liver was fully prepared during the first stage. Silicone vessels were looped around the right arteriobiliary pedicle and around the right hepatic vein. The remnant posterior sector is labeled remnant. The left liver living donor graft is labeled graft. (A, D) A large silicone sheath is placed to the right side of the IVC, dorsolateral to the liver and against the liver cut surface to encase the remnant. (B, E) The laparoscopic right remnant is resected with the division of the 2 vascular pedicles using an Endo-GIA (Medtronic) type stapling system.

in terms of hepatic drainage (segments 5 and 8 to the middle or right hepatic vein), arterial supply, and biliary variants, with an ELH being preferable to an LH for possible anterior biliary sectoral ducts draining into the left bile duct.

Fifth, the portal bifurcation should be resected during the first stage of the hepatectomy, as done for Klatskin tumors. This adaptation, in contrast to reports proposing a simple right portal branch ligature, is oncologically appropriate to secure the margins, and it is technically beneficial. The balance between traction forces of the portal tripod (the trunk and the right and the left branches) after right liver resection is found by aligning the portal trunk and the left branch. Thus, a portal anastomosis is less likely to kink if the donor left portal branch is directly sutured to the straightened recipient portal vein.

Sixth, the second stage can be performed via laparoscopy. The native liver can be fully prepared during the first stage by wrapping it to prevent adhesions and by marking the pedicles. These modifications allow for a comfortable residual hepatectomy with reduced surgical stress. Indeed, a fast postoperative recovery is highly desirable in view of prompt adjuvant chemotherapy.

To conclude, novel 2-stage LT strategies resolve the ethics debates around LDLT because limited donor hepatectomies reduce the risk of liver failure in donors. Likewise, leaving a residual native liver in recipients for a limited time protects from a possible temporary graft shortfall or technical failures during the crucial postoperative phase. Therefore, arterial thrombosis or inadequate graft volume growth and functional insufficiency (the small-for-size or small-for-flow syndromes) can be smoothly managed. This groundbreaking innovation gives small grafts time to regenerate, while the native liver acts as a stake that supports metabolic functions and prevents emergency listing of patients whose primary indication was controversial.

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