Liver resection, with or without chemotherapy, remains the only treatment with the potential for curing malignant liver tumors.1-3 Frequently, major liver resections are mandatory to achieve tumor-free surgical margins.4 One of the most severe complications associated with extended resections is posthepatectomy liver failure (PHLF). The best candidates for liver resection with curative intention are those who have enough parenchymal reserve, which should be at least 20% of the total liver volume in the case of a healthy future liver remnant (FLR),5,6 and between 30% and 40% in patients with chemotherapy-related liver injury, fibrosis or steatosis.7,8 Portal vein occlusion has become the gold standard strategy to regenerate the FLR with a low morbidity, allowing up to 20% to 35% hypertrophy in 45 days.9-11 However, up to 40% of patients treated with this approach are finally not candidates for resection, either because of tumor progression during the interval period or insufficient FLR hypertrophy.12 Recently, associating liver partition and portal vein ligation for staged hepatectomy (ALPPS) has been introduced as a strategy for preventing PHLF by rapid and effective hypertrophy of the FLR. The indications for this innovative surgical strategy include patients with marginally resectable or primarily nonresectable locally advanced liver tumors of any origin with an insufficient FLR in either volume or quality.16 With regard to the present surgical variation of the ALPPS approach, it is indicated in patients with bilateral disease and a high tumor load in the left lateral segment, precluding its use as a part of the FLR (Fig. 1). Preoperative volumetric analysis of the predicted FLR with multidetector CT or MR is a crucial element of surgical planning (Fig. 2).

**Stage 1**

The procedure begins with a bilateral subcostal incision with midline extension. The entire abdominal cavity is explored to rule out intra- or extrahepatic disease that might preclude resectability. Intraoperative Doppler ultrasound (IOUS) of the liver allows a correct evaluation of the vasculobiliary anatomy and its relationship with the tumor. The second stage is performed when sufficient hypertrophy of the FLR is demonstrated, usually as a right hepatectomy or trisectionectomy, leaving the left lateral segments of the liver (segments II and III) as part of the FLR. Here we describe a new surgical strategy using the principles of the ALPPS technique, preserving only segments I and IV as the FLR.

**SURGICAL TECHNIQUE**

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**Figure 1.** Surgical exploration demonstrating a liver with an extensive tumor load. Metastatic lesions are present in all segments of the liver. Segment IV clean up is planned to become part of the future liver remnant (dotted lines). (Drawing by Fanny Rodriguez Santos, MD.)
tumor lesions, monitoring the level of resection, the potential for resectability, and the detection of new lesions. Once resectability is confirmed, the left liver is mobilized by taking down the falciform, the left triangular, and the coronary ligaments. The next step is to mobilize the right lobe, including the right coronary and triangular ligaments, then isolate and divide all accessory hepatic veins localized in the right and anterior aspect of the inferior vena cava. The right hepatic vein is dissected and encircled. Cholecystectomy is performed and the cystic duct is marked for additional transcystic manipulation. Subsequently, the attention is directed toward the hepatoduodenal ligament, where a complete lymphadenectomy is carried out. This surgical maneuver has an oncologic purpose and is also helpful for the identification of anatomical variations (Fig. 3). The hepatic pedicle is encircled for the eventual need for a Pringle maneuver during liver partition. Then, an aggressive clean up of the hepatic lesions in the FLR (segments IV and I) is carried out, putting emphasis on not compromising the inflow or outflow of these segments (Fig. 4).

Before starting the parenchymal transection, the vascular inflow and outflow of segments I and IV (which will represent the FLR) should be assessed with IOUS after clamping the right portal vein. Once a proper vascularization is certified, the right portal vein is sectioned (Fig. 5) and liver partition is carried out through the Cantlie’s line. Cavitron ultrasonic surgical aspirator, in combination with the harmonic scalpel and cautery, is used for parenchymal partition. The anterior and posterior right hepatic pedicle branches are isolated and encircled with silks or vessel loops for better identification during the second stage (Fig. 6). During this step, it is important to prevent right hepatic artery injuries because it is the only vascular inflow of this hemi-liver. Careful

**Abbreviations and Acronyms**

ALPPS = associating liver partition and portal vein ligation for staged hepatectomy  
FLR = future liver remnant  
IOUS = intraoperative Doppler ultrasound  
PHLF = posthepatectomy liver failure

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**Figure 2.** (A) Preoperative liver volumetric MR in a 77-year-old patient with multiple bilateral colorectal liver metastases who received 6 cycles of chemotherapy. (B) The estimated future liver remnant volume (FLR) including segments I and IV was 305 mL. The FLR represented only 20% of the total liver volume.

**Figure 3.** Portal pedicle lymphadenectomy during the first stage of associating liver partition and portal vein ligation for staged hepatectomy. A black silk is around the portal triad. The left portal vein is encircled with a blue vessel loop, the right hepatic artery with a red vessel loop, and the left hepatic artery with a white vessel loop. Bile duct is pointed with an asterisk and the cystic duct with a black arrow.
control of hemostasis is performed with Argon beam, sutures, and hemostatic agents.

Once it is certified that the ALPPS is technically feasible, the resection of the left lateral segment due to high tumor load can be carried out (Fig. 7). The parenchymal transection line is marked 1 cm to the left of the falciform ligament to preserve segment IV vascular and biliary pedicles. The left lateral segment pedicle is dissected and ligated inside the umbilical plate. The ligament of Arantius is subsequently divided, and the confluence of the middle and left hepatic veins isolated. Finally, the left hepatic vein is sutured, isolating the left lateral segment from segment IV. At this point, an IOUS is performed to ensure adequate inflow and outflow of the FLR.

To detect biliary fistulas, a transcystic hydraulic test and cholangiography are routinely performed. To simplify the second stage, a plastic sheath is placed between the cut surfaces. Two drains are situated in the transection line and the right subphrenic space.

**Stage 2**

During postoperative day 6, a volumetric multidetector CT or MR of the FLR (segments IV and I) is performed to confirm liver hypertrophy and a tumor-free FLR. If the patient is in good condition and volumetric analyses showed a sufficient FLR hypertrophy, the completion surgery is scheduled for the next day.

The previous incision is used to enter the abdominal cavity. After releasing lax adhesions, the plastic sheath is removed and sent for microbiologic analyses. An IOUS is
performed in the FLR to certify a patent hepatic artery and portal vein. The anterior and posterior right pedicles that were encircled during stage 1 are recognized and ligated. The right hepatic vein is divided and sutured in a running fashion and the right hepatectomy is completed (Fig. 8). At the end of the procedure, a hydraulic test and cholangiography, whenever possible, are recommended to certify the absence of bile leaks.

DISCUSSION
Major liver resections continue to be associated with substantial morbidity and mortality, particularly related with PHLF. Portal vein occlusion remains the gold standard technique to guarantee a sufficient FLR. However, patients with diabetes or severe sinusoidal injury (a common situation in this population of patients) can be associated with impaired initial growth of the FLR.17 Up to 40% of patients are not candidates for surgical resection, because of either tumor progression or insufficient FLR hypertrophy. Embolization of segment IV portal branches carries a considerable risk of accidental thrombosis or injury to the left portal vein, which vascularizes the FLR.18 The ALPPS approach has emerged as a new surgical strategy to increase resectability in patients with locally advanced oncologic disease by rapid FLR hypertrophy. Schnitzbauer and colleagues13 described the initial multicentric German experience with the ALPPS technique in 25 patients with primary or metastatic liver tumors using the left lateral segments as part of the FLR. However, only patients with a tumor-free left lateral segment were included in the study. In our experience, we have included patients with multiple bilobar disease, in whom we performed the resection (clean up) of those lesions in the left lateral segment or the right posterior segments (VI and VII) as part of the FLR.16

Recently, Gauzolino and colleagues19 presented different technical variations of the ALPPS approach, including the “left ALPPS,” the “right ALPPS,” and the so-called “rescue ALPPS” in patients with failed portal vein embolization. However, there are no reports about the complete resection of segments II and III as an extreme clean up of the FLR when performing a right hepatectomy during ALPPS. In this situation, only segments I and IV constitute the FLR.

In this article, we highlighted the technical aspects that we believe are important to safely perform this original variation of the ALPPS approach. For the particular technical aspect of using a plastic sheath to minimize adhesions, the main disadvantage is that the patient might still require a reoperation to remove this foreign body if the second stage cannot be performed. With this in mind, other authors have reported on the use of absorbable material with favorable results.20 To date, we have treated 29 patients with the ALPPS approach and, in 2 patients, we used the technique described here. Both of those patients had colorectal liver metastases, were male, and were 69 and 77 years old. During the postoperative period, both experienced a mild elevation of the bilirubin levels that recovered before 72 hours after the second stage. Neither patient had PHLF, but pleural effusion, acute renal insufficiency, and inguinal hematoma developed in 1 patient due to a dialysis catheter, which prolonged the hospital stay. Both patients were discharged fully recovered at 15 and 43 days after the first-stage procedure. At follow-up, 1 patient is disease-free 7 months after surgery and the other patient died from brain metastases 5 months after the procedure.

Given the fact that the ALPPS approach is a very complex and challenging 2-stage procedure, it should be performed only by hepatobiliary specialists at high-volume centers.

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