The association of PVL and MWA creates an avascular groove between the cancer and the FLR. Furthermore, it avoids the formation of interlobar portoportal shunts and thus should protect from tumor progression with FLR invasion. Moreover, the pathophysiological events connected with the blockage of the portoportal shunts could enhance the FLR hypertrophy, as suggested by Schnitzbauer et al. We believe that a faster and easier minimally invasive first-step approach could minimize some surgical risks resulting in less complications and thus shorter hospital stay.

According to our knowledge, this is the first case described of minimally invasive laparoscopic PVL associated with MWA on the future hepatic resection plane for the treatment of extended liver tumors. We have named this surgical procedure “LAPS” (Laparoscopic microwave Ablation and Portal vein ligation for Staged hepatectomy). Randomized clinical trials will be necessary to test this new minimally invasive surgical approach. To this end, our institution has recently started a phase 1 study to test the safety and efficacy of LAPS in patients with locally advanced liver tumors. Finally, this surgical approach could be of benefit only in selected cases and should be performed in tertiary high-volume experienced liver centers.

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been found to be sensitive and specific in the early detection of liver failure.10 We believe that the performance of the ICG clearance test after parenchymal transection and selective inflow occlusion can directly assess the function of the future liver remnant. This may determine whether there is sufficient remnant to proceed with resection or whether, in the setting of insufficient remnant, an ALPPS procedure is required.

Our initial experience with this technique was with a 75-year-old man with bilobar colorectal liver metastases. Six cycles of FOLFOX chemotherapy resulted in near complete metabolic response on 18F-fluorodeoxyglucose positron emission tomographic scan. Laparoscopic segmental resection of a segment 4 lesion was performed, followed by right portal vein embolization with the initial surgical intention to complete oncological clearance with a staged right hemihepatectomy. Four weeks after portal vein embolization, CT volumetry indicated an adequate future liver remnant of 38% (623 mL) whereas hepatobiliary scintigraphy with Tc 99m hepatominodiacetic acid revealed a PDR of 20.2%/min with an R15 of 4.8%. Intraoperative ICG clearance was repeated with right hepatic arterial inflow occlusion can directly assess the function of the first stage of an ALPPS procedure. The right portal vein and the right bile duct were ligated and divided, and vessel loops were left around the right hepatic artery and the right hepatic vein to allow for easy identification. Seprafilm adhesion barrier (Genzyme, Cambridge, MA) was wrapped around the right hemiliver and applied under identification. Seprafilm adhesion barrier (Genzyme, Cambridge, MA) was wrapped around the right hemiliver and applied under the laparotomy wound. Drains were placed subhepatic and in the transection plane.

After the first stage of the ALPPS procedure, the patient had an uneventful course. Repeat CT volumetry after 12 days confirmed a 92% growth (1198 mL) of the future liver remnant to 60% of the total liver volume. Hepatominodiacetic acid volumetry on the same day revealed a future liver remnant function of 46% normalized to 5.9%/min/m². The second stage of the ALPPS procedure was performed 14 days after the first stage for logistical reasons. ICG clearance was repeated before the second stage, which showed a PDR of 20.2%/min with an R15 of 4.8%. Intraoperatively, before the irreversible step of right hepatic artery division, a further ICG clearance was repeated with right hepatic arterial occlusion. This showed an adequate future liver remnant PDR of 12.1%/min and an R15 of 16.3%. Postoperative course was significant for a prolonged ascitic drainage, which lasted until 12 days after the second stage. The patient was discharged after an overall admission of 30 days.

Intraoperative ICG clearance allows for the direct assessment of the actual future liver remnant function. Its advantage over CT volumetry is that it takes into account liver parenchymal disease. Its advantage over hepatominodiacetic acid volumetry, particularly before the first stage of ALPPS, is that it assesses the actual liver remnant that may be different from the preoperative estimation depending on the parenchymal transection plane or whether additional resection is required from the future liver remnant. Conversely, ICG clearance measurement requires stable hemodynamic parameters and its intraoperative utility is not established. We are now conducting a study to delineate this prospectively. ALPPS is an exciting new procedure; however, morbidity is significant and long-term oncological outcome is still uncertain.

We believe that it is a mountain worth climbing, given good disease biology as assessed by metabolic response to preoperative chemotherapy.13 In our recent experience of 5 ALPPS procedures, we have introduced it as an option only when staged resection with portal vein embolization had failed to produce adequate future liver remnant. We highlight the fact that the estimated future remnant size by volumetry does not necessarily equate to function and suggest a method to directly assess future liver remnant function. Intraoperative ICG clearance may be a useful “check” step to improve safety during liver resection in small-for-size settings.

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Radio-frequency-assisted Liver Partition With Portal Vein Ligation (RALPP) for Liver Regeneration

To the Editor:

Since the original article on Associating Liver Partition and Portal vein ligation for Staged hepatectomy (ALPPS) published in Annals of Surgery in March 2012 by Schnitzbauer et al, we have been reading with great interest the discussion surrounding this technique and present a new technique developed by a senior hepatobiliary and pancreatic surgeon (L.R.J.) at our hepatobiliary center. In our center, a novel technique has been described by our group,9 attention was paid to ALPPS, by using in-line radio frequency to create an virtual liver partition with portal vein ligation—Radio-frequency—Assisted Liver Partition with Portal vein ligation (RALPP). In-line radio frequency uses a probe with electrodes in one line and can produce a precise avascular area up to 1 cm using ImageJ (Image Processing and Analysis in Java, National Institutes of Health) as previously described.10 The FLR was measured as the left lobe of the liver to the left of the Cantlie line.

All patients had a right hepatectomy for colorectal liver metastases after either RALPP (n = 5) or PVE (n = 5). RALPP was performed laparoscopically as planned in 4 patients, as a part of stage I resection for bilobar disease with tumorectomy from segment II (n = 1), segment III (n = 2), and segment IV (n = 1). The median length of operation for these 4 cases was 140 minutes (range, 105–180 minutes). One patient had an open operation for RALPP, as it was felt intraoperatively that her tumor had progressed while waiting for operation and she would require a right hepatectomy to achieve R0 resection for her tumor, but her FLR was inadequate. One patient who had RALPP and a wedge resection of segment II metastases laparoscopically was readmitted a week after discharge with recurrent chest pain. She was known to have multiple pulmonary emboli after her colectomy and had an inferior vena cava filter inserted. Although it was unclear whether she had a new or old pulmonary embolus, she was treated with intravenous heparin. There was no other morbidity in RALPP group. In the PVE group, one patient developed a large pleural effusion posthepatectomy requiring drainage. No patients developed a postoperative bile leak in either group. There was no mortality at 90 days.

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Radio-frequency-assisted Liver Partition With Portal Vein Ligation (RALPP) for Liver Regeneration

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ince the original article on Associating Liver Partition and Portal vein ligation for Staged hepatectomy (ALPPS) published in Annals of Surgery in March 2012 by Schnitzbauer et al, we have been reading with great interest the discussion surrounding this technique and present a new technique developed by a senior hepatobiliary and pancreatic surgeon (L.R.J.) at our hepatobiliary center. Liver resection remains the gold standard treatment option for patients with primary or secondary liver tumors, providing

them with the only chance for long-term survival. In up to 45% of resectable cases, an extended hepatectomy is necessary to achieve a clear resection margin, a major determining factor for long-term survival.1,2 It is generally agreed that the future liver remnant (FLR) must be at least 25% to 30% of the liver volume to overcome problems related to liver insufficiency in patients with a healthy liver. This leaves only 10% to 20% of patients suitable for surgery at presentation.

Over the years, various methods have been used clinically to induce hypertrophy of the FLR preoperatively, with the aim of reducing postoperative complications and increasing the proportion of patients suitable for resection. Portal vein embolization (PVE) is the standard technique used clinically in patients with insufficient FLR before liver resection and can result in an increase in the FLR volume of 11.9%.3 Schnitzbauer et al4 proposed the alternative surgical method of ALPPS, where a much greater increase in the FLR volume of 74% was seen in a much shorter time period. However, the morbidity from this procedure3–6 is 33% to 64% compared with 16% after PVE.5 The morbidity after ALPPS is increased because of a high rate of postoperative bile leaks. A group from Bueno Aires tried to reduce the higher risk of biliary leak by wrapping the whole diseased ischemic liver in a hermetic plastic bag.5 However, their morbidity rate remained high at 58.0%.6 In Germany, a median hypertrophy rate as high as 87.2% was seen after performing ALPPS in 9 patients; however, the bile leak rate was still 22.2%.7

In our center, a novel technique has been described by a senior surgeon (L.R.J.) to achieve a rapid increase in FLR within a short period of time, as seen in ALPPS without the increased morbidity rates related to ALPPS, by using in-line radio frequency to create a virtual liver partition with portal vein ligation—Radio-frequency—Assisted Liver Partition with Portal vein ligation (RALPP). In-line radio frequency uses a probe with electrodes in one line and can produce a precise avascular area up to 1 cm wide. Between January and October 2013, 5 patients (3 men, 2 women) with a median age of 62 years (range, 48–71 years) underwent RALPP by L.R.J.

After resection of tumor from the left lobe, for those requiring staged liver resection with bilobar disease, as previously described by our group,8 attention was paid to hilar dissection for identification and ligation of the right portal vein. The portal vein was carefully separated from the common hepatic duct behind the right hepatic artery. Whenever possible, the right hepatic artery was isolated and slung with a nonabsorbable suture (2/0 Prolene) to aid identification and ligation of this at the second-stage liver resection. The right portal vein was isolated using blunt dissection and ligated using 2 Hem-o-loks (Teleflex, Asheboro, NC). After ligation of the right portal vein, the demarcation between the left and right lobes of the liver was clearly visible. Then, radio-frequency ablation with either Cool-tip radio-frequency ablation probe (Covidien, Hampshire, UK) for open case (n = 1) or Habib Sealer (LH4X, Rita) for laparoscopic case (n = 4) was performed for completion of RALPP along the line of the demarcation to segment VIII of the liver above the right hepatic vein superiorly and to segment V above the hilar on the left side of the gallbladder. A 5-port (2 × 10-mm working ports on each side of abdomen) technique was used for laparoscopic operation. All patients had a restaging computed tomographic scan with contrast to assess the liver volume before right hepatectomy.

We also examined a historical cohort of 5 patients who underwent PVE, matched for age, sex, initial liver function, and pathology, and compared the percentage increase in the FLR volume, 90-day morbidity and mortality, time to second operation, and liver function after completion hepatectomy on postoperative days 1 to 5. Liver volumes were calculated using ImageJ (Image Processing and Analysis in Java, National Institutes of Health) as previously described.10

The FLR was measured as the left lobe of the liver to the left of the Cantlie line. All patients had a right hepatectomy for colorectal liver metastases after either RALPP (n = 5) or PVE (n = 5). RALPP was performed laparoscopically as planned in 4 patients, as a part of stage I resection for bilobar disease with tumorectomy from segment II (n = 1), segment III (n = 2), and segment IV (n = 1). The median length of operation for these 4 cases was 140 minutes (range, 105–180 minutes). One patient had an open operation for RALPP, as it was felt intraoperatively that her tumor had progressed while waiting for operation and she would require a right hepatectomy to achieve R0 resection for her tumor, but her FLR was inadequate. One patient who had RALPP and a wedge resection of segment II metastases laparoscopically was readmitted a week after discharge with recurrent chest pain. She was known to have multiple pulmonary emboli after her colectomy and had an inferior vena cava filter inserted. Although it was unclear whether she had a new or old pulmonary embolus, she was treated with intravenous heparin. There was no other morbidity in RALPP group. In the PVE group, one patient developed a large pleural effusion posthepatectomy requiring drainage. No patients developed a postoperative bile leak in either group. There was no mortality at 90 days.

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