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Ultrasound liver map technique for laparoscopic liver resections: tips and tricks

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Abstract

Laparoscopic liver resection (LLR) is safer and more advantageous than open surgery regarding morbidity, blood loss, and length of hospital stay. Several radiological studies and liver surgical strategies confirmed that the anatomy of the liver is more complex than what Couinad described. Intraoperative ultrasound (IOUS) has become an indispensable tool to identify the "real anatomy" and to plan a tailored LLR because of wide sub-segmentary variability and lack of external indicators for small functional liver cores. We schematized our standard ultrasound guidance technique during anatomical and non-anatomical LLR as a four-step method called the Ultrasound Liver Map Technique: (1) Compose the three-dimensional mind map to study the relationships between lesions and surrounding vascular elements; (2) create a sketch on the Glissonian using cautery to help the surgeon recall the mind liver anatomy map; (3) check the section plane while proceeding with the transection; and (4) correct the direction of resection plan to ensure a healthy margin concerning the lesion and to point out the pedicle section correctly and not affected structures. Finally, IOUS-Doppler can be used to study the segmental portal flow to assess venous drainage of the remnant parenchyma, avoiding ischemia and increasing the possibility of performing parenchyma-sparing surgery.

Keywords: laparoscopic liver resection, minor anatomical resection, liver anatomy, intraoperative laparoscopic liver ultrasound

INTRODUCTION

Liver surgery has changed profoundly over time. Minimally-invasive approaches are spreading; the renewed enthusiasm for the study, diffusion, and application of anatomical liver studies have driven two significant revolutions that contributed to this evolution.

Two international and one European consensus conference recognized laparoscopic liver resection (LLR) as safer and more advantageous than open surgery regarding morbidity, blood loss, and length of hospital stay[1-3].

Several radiological studies and surgical strategies confirmed that the anatomy of the liver is more complex than what Couinad described. Takasaki *et al.* described "cone units" as the smallest anatomical parts of the liver supplied by a tertiary branch with bases on the liver surface and peaks toward the hilum[4]. Majno *et al.* reported a median number of 20 (range 9-44) of second-order branches given off by the left and right portal veins[5]. Based on these contributions, the Tokyo 2020 Expert Consensus Meeting described the presence of one to several tertiary pedicles in each segment[6]. They defined subsegmentectomy as a parenchymal resection within a portal segment inferior to the entire segment of Couinaud.

Because of these revolutions, modern liver surgery encompasses a wide range of LLRs based on the actual vascular-biliary anatomy that ranges from minor anatomical resections (ARs) to complex non-anatomical resections (non-ARs).

According to the anatomic variations of the secondary and tertiary branches of the hepatic veins and the portal pedicles and the absence of extrahepatic landmarks for these smaller liver units, intraoperative ultrasound (IOUS) became an indispensable tool to understand the actual anatomy and plan a tailored LLR.

The four-step[7-8] method (the "4 C's") is a valuable technique based on IOUS ability (rules 1 and 2) and resection counseling IOUS role (rules 3 and 4).

1. Compose the three-dimensional mind map. First, perform accurate ultrasound mapping of the parenchyma, understanding connections between the target nodules and the surrounding vascular structures.

2. Create the sketch. Deep vascular elements are brought back to the Glissonian of the liver surface using cautery to make a drawing. The aim is to guide the surgeon and help them recall the liver anatomy map relative to the target. Following the sketch, resection lines are marked on the Glissonian sheaf to bring the structures to the surface to be sectioned and preserved.

3. Heck the way. Only the deeper structures are shown on the map sketch as a Glissonian projection. For this reason, controlling the section plane while proceeding with resection by IOUS is helpful. The resection line can be easily visualized as an inhomogeneous hyperechoic artificial line in the parenchyma. Using this landmark, the surgeon can check the resection plane as needed during transection to respect the vascular structure margins.

4. Correct the direction, i.e., where to start the resection and the correct angle of incidence, which might be challenging to identify at the beginning. Using ultrasound, the surgeon can adjust the direction to keep away from the nodule, locate the pedicle at the appropriate section point, and preserve the uninvolved parenchyma.

The following section will describe the aid provided by IOUS during ARs and non-ARs.

Ultrasound-guided anatomical minor resections

ARs are challenging because of the shortage of clear dissection planes between various hepatic segments. Intersegmental/sectional borders are determined by (I) hepatic veins, (II) Glissonian pedicles, and (III) ischemic demarcation routes.

To execute an AR, transection planes are easily recognized by the surgeon using IOUS. Here we report an example of an S8 segmentectomy.

• The longitudinal plane runs along one or more hepatic veins. The first plane follows the right hepatic vein, and the second follows the middle hepatic vein (the lateral and medial parts of the line transection, respectively). Using IOUS with a probe sliding movement on the Glissonian sheet, there are longitudinal and transversal views. In this way, hepatic veins are easily identified.

• The transverse plane runs from the origin of the tributary portal stalks. In the case mentioned above, this plane runs along the anterior portal branch between the pedicles of segment 8 (to be ligated) and segment 5 (to be spared).

Surgeons who perform AR connect the longitudinal and transverse planes. IOUS helps verify and correct the resection plane immediately during the parenchymal transection phase. Once the tributary Glissonian pedicle is reached, it can be isolated and ligated.

The primary difference between the ventral and Glissonian pedicle-first approach[9] is the point of stalks reached during parenchymal transection (advanced and early phase, respectively). Thanks to intraoperative laparoscopic ultrasound (LUS), relevant portal peduncles are identified for anatomical segmentectomies and subsegmentectomies of segments 7 and 6 and Sg6-7 bisegmentectomies from the dorsal side of the liver after completion. Mini-hepatotomy is performed, and the right pedicle is identified, dissected, and clamped.

The final highlight for AR is the ischemic zone on the Glissonian surface. Using intraoperative ultrasound (LUS or IOUS), selective ligation or clamping of portal pedicles can be easily performed with the ventral or the Glissonian pedicle-first approach to highlight the ischemic area. We note that parenchymal resection could also be facilitated using the indocyanine green fluorescence technique because indocyanine injection makes ischemia evident even deep in the parenchyma while primarily clamping on the surface.

Ultrasound-guided non-anatomical resections

IOUS/LUS guidance is pivotal for the non-anatomical resection of Glissonian pedicles and the hepatic veins surgical approach.

• LUS/IOUS allows Glissonian pedicle detection at the proper point of ligation. During dissection, to check these structures, IOUS/LUS prevents iatrogenic injuries of tributaries to disease-free liver parenchyma and reduces the risk of hemorrhage.

• Hepatic veins are the proper boundaries between subsegments or segments. IOUS/LUS helps to identify hepatic veins and their routes in the parenchyma. Using IOUS/LUS, hepatic veins are approached from the root or peripheral sides according to the tumor position, type of segment, and liver morphology, minimizing bleeding and split-vein damage.

Evaluation of venous drainage of the remnant liver

Major or extended hepatectomies are often required for tumors involving the hepatic veins at the hepatocaval junction. The risk of congestion ischemia must be assessed to plan the proper type of liver resection for these lesions. Intraoperative color-Doppler ultrasound (described for the first time by Sano *et al.*[10]) is crucial to verify venous congestion of the remanent liver, owing to concomitant and reversible hepatic vein clamping. If the remnant liver does not find alternative vein drainage (e.g., veno-venous shunts or accessory veins), the parenchyma will develop a variable and inconstant area that is not perfused or is congested along the cut surface[11]. This condition should be prevented to avoid postoperative morbidity (bile leakage and bleeding) and poor long-term outcomes[12]. As recently shown, persistent imbalance of inflammatory cytokines caused by ischemic residual liver leads to altered immunological states. This condition facilitates tumor progression and affects oncology results after partial resection for hepatocellular carcinoma and colorectal liver metastases[13].

CONCLUSION

IOUS is an essential tool for laparoscopic anatomic and non-anatomic liver surgery. Ultrasound liver map technique allows real-time planning and direction during laparoscopic liver resections.

Video comments

Video 1

The video [Supplementary Video 1] displays a 75-year-old woman with left colon adenocarcinoma and seven liver metastases (LMs). First, she underwent chemotherapy with six cycles of oxaliplatin-based therapy. She obtained a partial response and then underwent a procedure according to the “liver first” strategy. She underwent preoperative staging with CT-Scan and magnetic resonance imaging. Both highlighted six LMs: 15 mm in Sg3 infiltrating the left hepatic vein (LHV), 20 mm in Sg4a adhering to the middle hepatic vein (MHV), the larger about 22 mm in Sg7-8d in a tight connection with a portal pedicle of Sg7 (P7) and the right hepatic vein (RHV), 10-mm in Sg6, 11-mm in the Spiegel lobe (SL). Finally, in the caudate lobe (CL), one LM (known at diagnosis) was no longer detectable (disappeared liver metastasis, DLM).

IOUS verified the location and vascular contacts of all LMs and discovered a DLM (5 mm) in the CL. First, we performed right liver mobilization to obtain extrahepatic control of the right hepatic vein. The RHV was clamped, and color-Doppler LUS flow analysis was performed. Hepatofugal inflow was found in venous occlusive segment 8 lateral (Sg8l). Finally, LUS facilitated planning for six resections: the first including Sg4a, Sg8, and Sg7 with the RHV preserved, the second for three lesions in Sg8l with MHV, the third for the SL, the fourth, fifth and sixth were subsegmentectomies and atypical resections of Sg3, Sg6, and CL, respectively. Inflow and outflow were controlled.

Regarding the vascular approach, to isolate P7 on the back liver surface, an LUS-guided pedicle-first approach was carried out. To dissect the MHV and RHV, the cranio-caudal method was used, and the LM in Sg4a was freed from the MHV. At the end of the procedure, all hepatic veins were exposed on the resected liver slice. We calculated a blood loss of about 400 cc. Transection and intermitting clamping times were 298 and 203 min, respectively. The postoperative period was uneventful, and the patient was discharged on the fourth postoperative day.

Video 2

This is an example of how to perform an intraoperative ultrasound to study all primary liver anatomic landmarks (portal and hepatic vein systems) [Supplementary Video 2].

DECLARATIONS

Authors' contributions

Made substantial contributions to conception: Russolillo N, Langella S, Tesoriere RL, Zingaretti CC, Fontana AP, Ferrero A

Provided administrative, technical, and material support: Russolillo N, Langella S, Tesoriere RL, Zingaretti CC, Fontana AP, Ferrero A

Draft and revise the work: Russolillo N, Langella S, Tesoriere RL, Zingaretti CC, Fontana AP, Ferrero A

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All authors declared that there are no conflicts of interest.

Ethical approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

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