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INNOVATIVE SURGICAL TECHNIQUES AROUND THE WORLD

Ultrasound Liver Map Technique for Laparoscopic Liver Resections

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Abstract

Background Laparoscopic liver resection (LLR) is reported as a safe procedure with potential advantages over open surgery albeit with inherent limitations, such as loss of haptic perception and spatial orientation. Ultrasound is considered the best tool to identify anatomic landmarks and the transection plane during liver surgery. The aim of this study was to analyse the outcomes of LLR performed with a standardized US guidance technique.

Methods We have standardized a 4-step technique for ultrasound-guided LLR: (1) compose a 3-D mind map by studying relationships among lesions and surrounding anatomic structures, (2) sketch the map on the liver surface, (3) check, and (4) correct the transection plane in real time.

Results Between 01/2006 and 12/2016, 190 consecutive patients treated with US-guided LLR were analysed. The indications for LLR included malignant tumours in 148 patients (81.8%). The procedures were classified according to a difficulty scale. There were 18 major hepatectomies (9.9%), 80 anatomic bi- and monosegmentectomies (44.2%), and 101 non-anatomic resections (55.8%). Redo resection was performed in 17 patients (9.4%), and multiple liver resections were performed in 25 patients (24.7%). Median intraoperative blood loss was 100 ± 154 mL. Overall and major morbidity rates were 14.9% and 1.6%, respectively. Mortality was nil.

Conclusions Ultrasound liver map technique enables planning and real-time guidance during laparoscopic liver resections.

Introduction

Laparoscopic liver resection (LLR) has gained widespread acceptance in recent years [1] and has been reported as a safe procedure with potential advantages over open surgery in terms of morbidity, blood loss, and post-operative hospital stay [2].

Because of the difficulty identifying anatomic landmarks and the surgical transection plane during LLR, minor resections are often more challenging than major hepatectomies. Known techniques of resection guidance are the ultrasound-guided injection of dye into the portal pedicle supplying the cancer [3] and ultrasound-guided vessel compression [4]. However, neither technique is easily reproducible during LLR. Machado et al. [5] proposed a technique in which glissonian pedicles are encircled and divided extrahepatically, but segmentectomy of the right segments, subsegmentectomy, and wedge resection of deep lesions are not suitable for this approach. Ultrasound is a useful tool to overcome these limitations; it allows the surgeon to see beyond the surface and provides real-time feedback during all types of hepatectomy [6].

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We present our experience of LLR in a series of patients with systematic and intensive use of ultrasound guidance.

Materials and methods

The study population included all consecutive patients treated with LLR between 01/2006 and 12/2016 at our centre. All resections were performed with a totally laparoscopic approach. The selection of the laparoscopic approach was considered each time and was based on the number and position of the liver lesions and the possibility of obtaining a parenchyma-sparing resection when indicated. A difficulty scale (DS) score ranging from 1 to 10 [7] was applied to each procedure. In patients who received multiple liver resections, the higher DS was chosen.

Ultrasound liver map technique

Because LUS is more complex than IOUS, we further schematized our standard technique for ultrasound guidance for resection as a 4-step method, which we call the ultrasound liver map technique. Using the mnemonic 4 *C's*, the 4 steps are:

1. Compose the 3-D mind map (Video1). The first step is to perform an in-depth ultrasound study of the relationships between the lesion and the surrounding vessels that are to be correctly identified in order to create a 3-D anatomic mind map (Fig. 1).
2. Create the sketch (Video2). The underlying anatomic structures are sketched on the liver surface with cautery, as previously described (9), the goal being to help the surgeon to hold in mind the map of the liver anatomy relative to the lesion. Lines of transection are drawn according to the sketch, thus planning which vessel will be ligated and cut and which will be preserved and exposed on the cut surface (Fig. 2).
3. Check the way (Video3). The map sketch shows only the glissonian projection of deeper structures, so it is necessary to check the section plane while proceeding with the transection. The resection line is easily visualized as an inhomogeneous hyperechoic linear artefact in the parenchyma, so the surgeon can check the resection plane, with respect to the relationships with hepatic veins, portal pedicles, and surgical margin, at any time (Fig. 3).
4. Correct the direction (Video3). The direction of the section plane is not always initially correct. The right angle of incidence at which to start the resection may not be obvious; often the direction has to be adjusted to stay clear of the lesion, to reach a pedicle at the correct distance from its origin, or to reach a structure that will be spared and followed (Fig. 4).

Surgical procedure

For resections involving left segments or segment Sg5, the patient was placed supine, in mild reverse Trendelenburg position, with the lower limbs apart and the operating surgeon between patient's legs. For resection involving segment Sg6, Sg7, or Sg8, the left lateral decubitus position was adopted. LUS was performed using a ProSound Alpha 7 ultrasound system with a UST-5536-7.5 probe (Hitachi Aloka Medical, Ltd., Tokyo, Japan) with 2-way and 4-way linear array laparoscopic transducers. Before 2010, parenchymal transection was performed most often with a radiofrequency sealer–divider (LigaSure^{TM}; Covidien, Mansfield, MA, USA) and bipolar coagulation, and

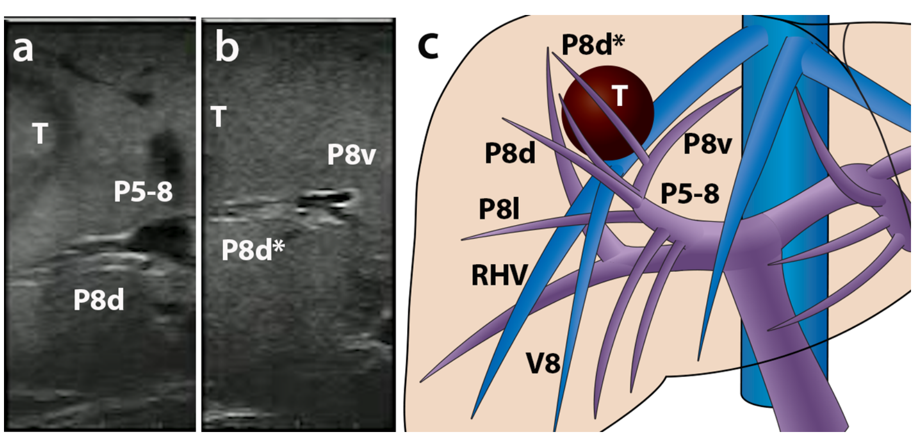

Fig. 1 Segment 8 dorsal laparoscopic resection. Compose the 3-D mind map. **a**, **b** LUS study of the relationships between the tumour (T) and the surrounding vessels: the right anterior portal branch (P5-8), the dorsal (P8d), and ventral (P8v) branch of Sg8. A dorsal branch of Sg8 (P8d*) originates from P8v. **c** Schematic representation of the 3-D anatomic mind map. RHV: right hepatic vein, V8: venous branch of the RHV draining the lateral portion of Sg8 and Sg5, P8 l: lateral branch of Sg8

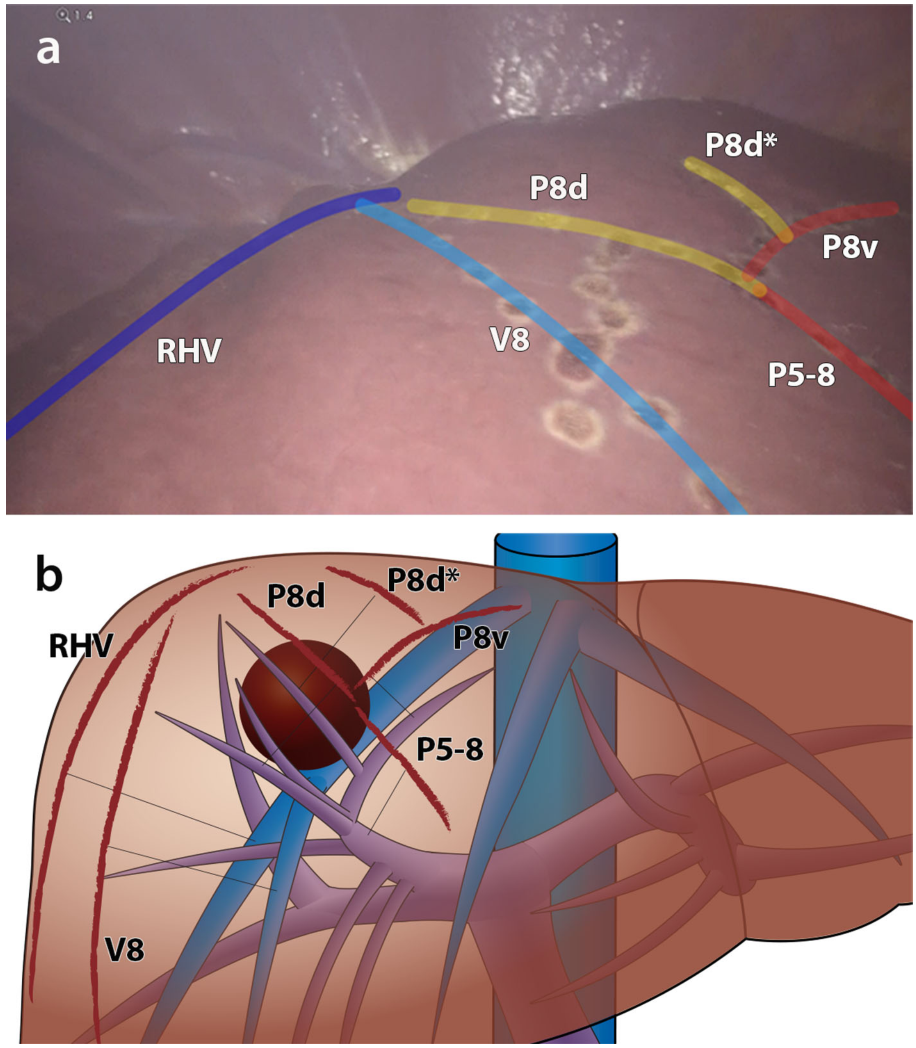

Fig. 2 Segment 8 dorsal laparoscopic resection. Create the sketch. **a** The anatomic structures have been sketched on the liver surface with the cautery. **b** Schematic representation of the map drawn on the liver surface

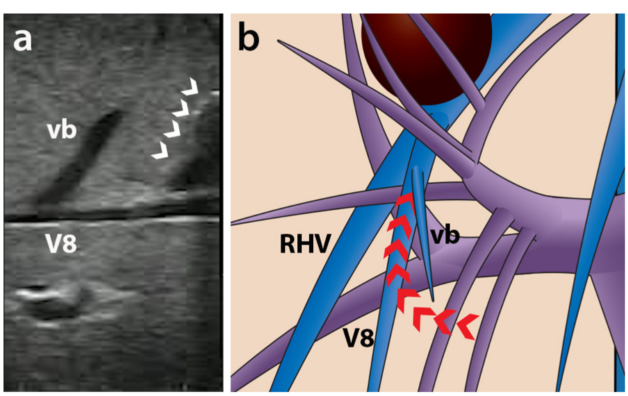

Fig. 3 Segment 8 dorsal laparoscopic resection. Check the way. **a**, **b** The section plane (arrowheads) is checked. The section is about to reach V8 that will be followed and exposed on the cut surface. Small venous branches (vb) will be divided

subsequently, an ultrasonic dissector (SonaStar® Laparoscopic Probe [MXA-L002]; Misonix, Inc., Farmingdale, NY, USA) combined with a radiofrequency sealer–divider (LigaSure™, Covidien) has routinely been used.

Definitions

Major hepatectomy was defined as the resection of >3 Couinaud's segments. Morbidity included all post-operative complications and was graded according to Clavien–Dindo classification [8]. Complications of grade III or higher were defined as major morbidity. Cumulative post-operative morbidity was assessed using the Comprehensive Complication Index (CCI®) [9], which measures overall morbidity on a scale from 0 (uneventful) to 100 (death). Technical complexity of LLR was defined according to the DS score [7].

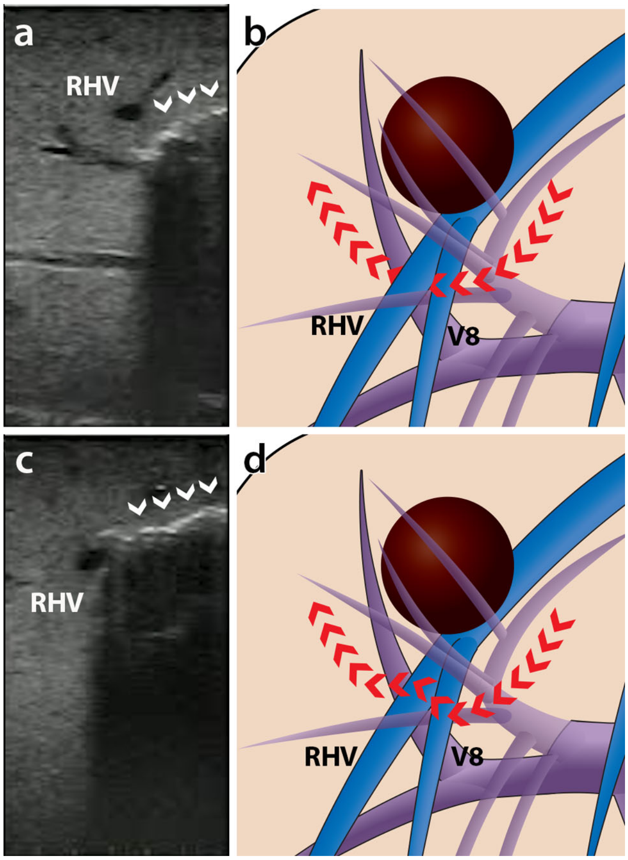

Fig. 4 Segment 8 dorsal laparoscopic resection. Correct the direction. **a**, **b** The direction of the section plane (arrowheads) is incorrect, running below the RHV that would eventually be included in the resection. **c**, **d** The direction has been corrected and runs above the RHV that will be spared and followed

Results

Patient characteristics and perioperative outcomes

A total of 190 LLRs were performed during the study period. Conversion to open technique was required in 9 patients (4.7%). Conversions were the result of intraoperative bleeding in three cases, IOUS findings in four cases, and dense adhesions in two cases. Perioperative data of the remaining 181 patients were analysed and are summarized in Table 1. Overall and major morbidity rates were 14.9% and 1.6%, respectively. Mean CCI was 3.7 ± 10. One patient developed post-operative liver failure, 4 bile leakage, and 4 ascites. Abdominal bleeding occurred in 1 patient, lung infection in 7, and sepsis in 3. Mortality was nil. Median intraoperative blood loss was 100 ± 154 mL. Two patients (1.1%) required post-operative blood transfusion. Median length of hospital stay was 5 ± 7.3 days.

Table 1 Preoperative characteristics and intraoperative data

Parameters	*n* = 181 *n* (%)
Male	109 (60.2)
Age (median, range, years)	66 (27–88)
Diagnosis	
Malignant lesions	148 (81.8)
Colorectal metastases	82 (45.3)
Hepatocellular carcinoma	43 (23.8)
Intrahepatic cholangiocarcinoma	9 (5)
Non-colorectal metastases	14 (7.7)
BMI	24.5 (15.4–37.3)
ASA 3–4	75 (41.4)
Redo resection	17 (9.4)
Major hepatectomy	18 (9.9)
Minor anatomic liver resection	80 (44.2)
Non-anatomic resections	101 (55.8)
Resection of postero-superior segments	101 (55.8)
Difficulty grade scale (mean ± DS)	3.9 ± 2
Multiple liver resections	25 (24.7)
Redo resections	17 (9.4)
Associated intestinal resections	11 (6%)
Pedicle clamping	56 (30.9)
Hepatic vein exposition on cut surface	39 (21.5)
Portal pedicle exposition on cut surface	19 (10.5)
Cut surface area (cm^2, median, DS)	39 ± 32.2
Transection time (min, median, DS)	80.5 ± 51

BMI body mass index, *ASA* American Society of Anesthesiologists score

Discussion

Laparoscopic liver surgery has evolved rapidly over the past 5 years as confirmed by the second International Consensus Conference on Laparoscopic Liver Surgery [1]. With growing experience and better instrumentation, there was a clear trend towards increasing proportion of major and complex resections such as parenchymal sparing surgery of deeply located lesions and anatomic segmentectomies of postero-superior segments. As in other centres, our LLR program started with simple minor resections in anterolateral segments. However, with development of the program, there was a clear trend towards employing LLR more often for major and complex resections. The main difficulties in these procedures concern the identification of the anatomic landmarks and surgical transection plane. At this moment, accurate real-time imaging of liver anatomy and resection plan are obtained only with intraoperative ultrasound. The present study analysed the post-operative results of LLR performed with a standardized ultrasound guidance technique.

The ultrasound liver map technique was borrowed from open liver surgery. In fact, in our centre, all liver resections, both open and laparoscopic, are performed under constant US guidance. Significant bleeding is more difficult to control during LLR than during an open approach [10]; indeed, intraoperative bleeding is the main cause of conversion [11]. We hypothesize that major vascular injuries can be avoided under real-time US guidance during LLR. It is interesting to note that the median intraoperative blood loss was about 100 mL. The small volume of intraoperative blood loss, the absence of major bleeding (>1 L), and the consequent low rate of blood transfusion could indicate the effectiveness of ultrasound guidance. Another important advantage of the ultrasound liver map technique is that it allows to follow the map inside the parenchyma thanks to the continuous verification and correction of the surgical plane that can be easily recognized by US, thus allowing the operator not to damage vascular structures that should be spared. The high rates of hepatic veins and portal pedicles exposition on the cut surface in the present series demonstrate the accuracy of US-guided parenchymal dissection.

Conclusion

Ultrasound liver map technique enables planning and real-time guidance during laparoscopic liver resections.

Compliance with ethical standards

Conflict of interest The authors declare they have no conflict of interest.

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