Usefulness of Intraoperative Real-Time Tissue Elastography During Laparoscopic Hepatectomy

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Recent technologic innovations and advances in surgical techniques have improved the feasibility and safety of laparoscopic hepatectomy (LH).[1-5] One theoretical disadvantage of LH is the lack of manual palpation and tactile feedback. Such a disadvantage hinders identification of tumors, especially when they cannot be visualized by intraoperative ultrasonography (IOUS). Surgeons may fail to precisely tailor the extent of parenchymal excision when they cannot use tactile feedback or hold the liver parenchyma for resection.

Real-time tissue elastography has been used to differentiate solid tumors of the breast, thyroid, prostate, and liver during open surgery.[6-12] Such elasticity images are also expected to be useful during laparoscopic surgery. However, no published series to date have focused on the advantages of intraoperative real-time tissue elastography (IRTE) during LH. The aim of this study was to perform IRTE examination of the liver using the laparoscopic approach and to evaluate its usefulness for LH.

METHODS

Patients

The subjects comprised 7 Japanese patients and 7 French patients. The Japanese patients underwent LH for malignancies including hepatocellular carcinoma (HCC), cholangiocellular carcinoma, and metastases of colorectal carcinoma and neuroendocrine tumors at Asahi General Hospital from February 2013 to May 2013. The French patients underwent LH for colorectal liver metastasis at the Institut Mutualiste Montsouris, Université Paris Descartes from June 2014 to July 2014. The IRTE examinations were performed by 1 surgeon (YK) at the former institution and 2 (YK or BG) at the latter. In addition to IRTE, all 7 Japanese patients were examined using contrast-enhanced intraoperative ultrasonography (CE-IOUS) with perfluorobutane microbubbles as a contrast agent (Sonazoid; GE Healthcare). All operations were performed after obtaining informed consent from each patient. The local institutional review boards approved this study.

Intraoperative ultrasound system

In this study, we used the Prosound α7 ultrasound system (Hitachi-Aloka Medical) and UST-5418 laparoscopic probe (Hitachi-Aloka Medical). This system and probe facilitate IRTE based on the combined autocorrelation method algorithm, which produces elasticity images with high-speed processing and high accuracy.[7,13] Elasticity images were scaled by colors depending on the strain magnitude: red for components with greatest strain (softest components), green for those with average strain in the range of interest, and blue for those with no strain (hardest components). These color-scale elasticity images were obtained while slightly vibrating the laparoscopic probe on the liver surface and were superimposed on the corresponding B-mode images. All lesions were classified using the modified elasticity type of liver tumor classification.[12]

Comparison of brightness of tumors with surrounding liver parenchyma in B-mode images

The brightness of the tumors and surrounding liver parenchyma in B-mode images was calculated using luminance-analyzing software (U11437; Hamamatsu Photonics)[14] to evaluate the ability of B-mode IOUS examination to differentiate tumors (Fig. 1).

RESULTS

Overall outcomes of intraoperative ultrasonography and intraoperative real-time tissue elastography in laparoscopic hepatectomy

Seventeen tumors of 14 patients were examined using B-mode IOUS and IRTE during LH (Table 1). The median (range) tumor size among all 17 lesions was 20 mm (range

Disclosure Information: Nothing to disclose.
Support: This work was supported by grants from the Japanese Foundation for Research and Promotion of Endoscopy.

Received June 11, 2015; Revised July 28, 2015; Accepted July 31, 2015.
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http://dx.doi.org/10.1016/j.jamcollsurg.2015.07.453
ISSN 1072-7515/15

Abbreviations and Acronyms

CE-IOUS	= contrast-enhanced intraoperative ultrasonography
HCC	= hepatocellular carcinoma
IOUS	= intraoperative ultrasonography
IRTE	= intraoperative real-time tissue elastography
LH	= laparoscopic hepatectomy
OH	= open hepatectomy

8 to 90 mm). The median (range) brightness ratio of the tumors to that of the surrounding liver parenchyma was 0.81 (range 0.01 to 1.08) (Fig. 2). The brightness ratio of 6 of these 17 lesions (35.3%) ranged from 0.97 to 1.08, and their margins were ill-defined in B-mode images; in other words, these 6 lesions were iso-echoic in fundamental B-mode images. In contrast, IRTE examination allowed visualization of all 17 tumors by depicting elasticity of the tumors and liver parenchyma in different colors depending on their elasticity. Fourteen adenocarcinomas were classified as type 6, with a sensitivity and accuracy of 100%. One HCC was classified as type 1, and another was identified as type 1/3. There was no appropriate elasticity type for 1 neuroendocrine tumor with necrosis.

Representative cases of intraoperative real-time tissue elastography during laparoscopic hepatectomy

Virtual palpation

A 69-year-old man (Patient 2 in Table 1) who had undergone hand-assisted laparoscopic partial gastrectomy for a gastric neuroendocrine tumor presented with a liver metastasis in segments V and VIII. Computed tomography with contrast material revealed a tumor measuring 5 cm in diameter, the marginal regions of which were well enhanced in both the arterial and portal phases (Fig. 3). Additionally, T2-weighted magnetic resonance imaging revealed a region of hyperintensity in the tumor, which suggested a fluid component related to necrosis. The laparoscopic approach was selected for the patient. After encircling the hepatoduodenal ligament with an umbilical tape for inflow occlusion (Pringle maneuver), IOUS of the tumor demonstrated a center with no to minimal echogenicity surrounded by iso- to hypo-echoic regions (Fig. 3). We concomitantly applied IRTE, which enabled visualization of the hard tumor containing soft components compared with the consistency of the liver parenchyma (Fig. 3 and Supplementary Video 1, available online). Based on this information, we ligated the Glissonian pedicle of segment V before transecting the liver to prevent bleeding from the soft components and planned to secure sufficient margins from the tumor to avoid rupture, especially when the hard structure was thin, such as in the region indicated by the white arrowhead in Figure 3D. Manual palpation could facilitate parenchymal transection if this resection were performed with an open approach. After ligation of the Glissonian pedicle V, the resection line was tailored by applying IOUS, after which anatomic resection of segment V was performed (Supplementary Video 1, available online). The postoperative course was uneventful, and the patient was discharged on postoperative day 5.

Identification of ill-defined margin of colorectal liver metastases after chemotherapy

A 66-year-old woman (Patient 6 in Table 1) who had undergone high anterior resection for a rectal adenocarcinoma was treated using capecitabine and oxaliplatin as adjuvant chemotherapy. She presented with 4 metachronous liver metastases, in segments III, V, VI, and VII. The tumor located in segment V was demonstrated as an iso- to hyper-echoic lesion by IOUS, and its margin was not clearly defined, most likely because of the influence of the preoperative chemotherapy. Subsequently, IRTE differentiated the tumor from the surrounding liver parenchyma because the hard tumor was visualized as blue in contrast to the surrounding liver parenchyma, which was visualized as green (Fig. 4). The tumor was also examined using CE-IOUS, which clearly demonstrated its margin. Wedge resection of segments III, V, VI, and VII was performed to secure sufficient margins from the tumor with reference to B-mode IOUS, CE-IOUS, and IRTE. The postoperative course was uneventful, and the patient was discharged on postoperative day 5.

Identification of ill-defined margin of a small hepatocellular carcinoma

A 54-year-old woman (Patient 7 in Table 1) was scheduled for surgery because of an HCC measuring 15 mm in diameter and located in segment V on a background of chronic hepatitis C (Child-Pugh class A). After insertion of trocars and insufflation of the abdominal cavity, the tumor was examined using B-mode IOUS, IRTE, and CE-IOUS. The border of the tumor was unclear because it was small and located close to the liver surface. The IRTE examination differentiated the tumor from the surrounding liver parenchyma because the tumor was visualized in a red color in contrast to the liver parenchyma, which was visualized as a blue color (Fig. 5). The HCC was softer than the liver