Tape-Guided Pure Laparoscopic Hepatectomy for Laterally Located Tumors: A Technique to Yield an Appropriate Tumor-Free Surgical Margin and to Make Parenchymal Transection Easier

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In the last decade, laparoscopic hepatectomy has become one of the standard therapies to treat malignant hepatic tumors.1,2 There have been many reports concerning its minimal invasiveness and its benefits.3-7 Pure laparoscopic hepatectomy (PLH) is a hepatectomy procedure in which parenchymal transection and mobilization of the hepatic lobes are accomplished completely inside a closed peritoneal cavity using only forceps or instruments that can pass through thin ports.8,9 Although PLH is considered less invasive than laparoscope-assisted hepatectomy or hand-assisted laparoscopic hepatectomy, there are several drawbacks to performing PLH. First, it is difficult to precisely identify tumors to be resected, especially tumors located deep in the liver parenchyma, because surgeons cannot palpate tumors in PLH and because there is a limited flexibility of an echo probe for intraoperative ultrasound, which is inserted through a fixed port. Second, surgeons cannot easily adjust the direction of the dividing plane in PLH. In order to overcome these problems, we applied a simple cotton tape to PLH. We previously reported tape-guided right posterior sectionectomy for tumors abutting the superior or inferior right hepatic vein.10 The cotton tape is easily identified as a hyperechoic line by ultrasound, which enables surgeons to easily determine an appropriate dividing plane. Moreover, the tape raises the dividing plane upward, making parenchymal transection easier. We applied this technique to PLH.

Six patients with a solitary solid tumor underwent tape-guided PLH between November 2012 and April 2013. Patient characteristics are summarized in Table 1. Preoperative diagnoses were hepatocellular carcinoma in 5 patients and intrahepatic cholangiocarcinoma in 1. Patients 4 and 6 had previously undergone their first hepatectomy for hepatocellular carcinoma in segment 8 and intrahepatic cholangiocarcinoma in segment 7, respectively.

Patients 1, 2, 3, 4, and 6 were placed in the supine position; Patient 5 was placed in the left lateral decubitus position. A skin incision measuring approximately 1.5 cm was made around the umbilicus. The first port, measuring 12 mm in diameter, was placed through this periumbilical incision. A pneumoperitoneum was then created with CO2. The pneumoperitoneum was maintained at a pressure of 8 mmHg (increased to a pressure of 10 mmHg during parenchymal transection). Four additional ports, 1 measuring 12 mm in diameter and 3 measuring 5 mm in diameter, were inserted as shown in Figure 1. The left or right triangular ligament was divided in order to mobilize the liver. The tumors were identified using intraoperative laparoscopic ultrasound (Aloka). A cotton tape, 9 mm wide and 30 cm long, was inserted into the peritoneal cavity and placed just under the presumed dividing plane. The tape was easily identified by ultrasound as a hyperechoic line (Fig. 2). The dividing plane between the echo probe and the hyperechoic tape that yielded an appropriate tumor-free surgical margin was determined. The anterior and posterior surfaces of the dividing plane were marked with electrocautery. Two traction sutures were placed on both sides of the dividing line. Parenchymal transection was accomplished using a vessel sealing device, BiClamp, with a voltage-controlled electrosurgical generator, VIO300D (ERBE), as previously described.11 Relatively large intrahepatic Glisson branches and hepatic veins (more than about 4 mm in diameter) were tied, clipped, and then divided. A deeper part of the dividing plane was raised anteriorly by pulling up the tape in order to make the parenchymal transection easier (Fig. 1). Resected specimens were taken out of the peritoneal cavity by extending the periumbilical wound (approximately 4 cm in length). A 15-F closed drain was inserted near the cutting surface of the liver; it was removed on postoperative day 1 after confirming there was neither bleeding nor bile leakage (see supplemental video, which demonstrates the procedure performed in Patient 6).
Operative results are summarized in Table 2. Although encircling the hepatoduodenal ligament for the Pringle maneuver was done in Patients 1 and 5, only the PLH for Patient 5 needed the Pringle maneuver. We applied the Pringle maneuver only when bleeding hindered clear visualization of liver parenchyma during parenchymal transection. The median operation time was 355 minutes (range 186 to 613 minutes). The median intraoperative blood loss was 30 g (range minimal to 127 g). All resected specimens had an appropriate tumor-free surgical margin (range 3 to 15 mm). Patient 6 had advanced cirrhosis, so we determined that the dividing plane was set at the immediate vicinity of the tumor border in order to preserve the functional parenchymal volume as much as possible. No postoperative complication occurred in these patients. These patients were allowed to leave the hospital when they felt confident that they could live in their home by themselves. The median postoperative hospital stay was 8.5 days (range 6 to 13 days).

An ideal resection procedure for hepatocellular carcinoma is an anatomic hepatic resection. Anatomical hepatectomy is associated with a lower recurrence rate and a better long-term survival rate than non-anatomic resection. However, a purely laparoscopic anatomic resection is not feasible in all patients. Therefore, we have been developing an alternative method for anatomic resection: tape-guided pure laparoscopic hepatectomy. This method is safe and effective, and we have confirmed its usefulness in several cases. The division plane for pure laparoscopic segmentectomy is determined by using a cotton tape and intraoperative ultrasound. The resulting division plane is determined to be an appropriate tumor-free surgical margin. The median tumor-free surgical margin was 1.2 mm. The median tumor-free surgical margin for Patients 2 and 3 was 1.1 mm. The median tumor-free surgical margin for Patient 4 was 0.8 mm. The median tumor-free surgical margin for Patient 5 was 1.3 mm. The median tumor-free surgical margin for Patient 6 was 0.9 mm. We believe that the present technique is safe and effective for intrahepatic tumors and can be a useful alternative to purely laparoscopic anatomic hepatectomy.

Table 2. Patient Characteristics

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<tr>
<th>Patient no.</th>
<th>Age, y</th>
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<td>6</td>
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<td>Male</td>
<td>ICC</td>
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CH-B, chronic hepatitis B; CH-C, chronic hepatitis C; CH-ETOH, alcoholic hepatitis; HCC, hepatocellular carcinoma; ICC, intrahepatic cholangiocarcinoma; LC-C, cirrhosis caused by hepatitis C; LC-ETOH, cirrhosis caused by alcoholic hepatitis; S, segment.

Figure 1. Schematic diagrams of tape-guided pure laparoscopic hepatectomy for tumors located in segments 2 or 3 (A) and for tumors located in segment 6 (B). a, 5-mm port for forceps to pull up the cotton tape; b, 5-mm port for a suction/irrigation tube; c, 12-mm port for a laparoscope; d, 5-mm port for forceps to pull up the cotton tape; e, 12-mm port for BiClamp forceps.

Figure 2. A schematic diagram showing how to determine the dividing plane using a cotton tape and ultrasound. Intraoperative ultrasound identified a tumor (A). A cotton tape was placed just under a presumed dividing plane. The tape was easily identified by ultrasound as a hyperechoic line (B). An appropriate dividing plane between the echo probe and the hyperechoic tape, which yielded an appropriate tumor-free surgical margin, was determined. Arrow heads indicate the tumor; arrows indicate the cotton tape, which is depicted as a hyperechoic line.
life. Patient 3 had simultaneous advanced rectal cancer and was scheduled to undergo systemic chemotherapy after PLH. Therefore, minimally invasive tape-guided hepatectomy could also be justified in this patient.

The average operation time seemed longer than times in other published reports. The most time-consuming part of our procedures was parenchymal transection, which was a major drawback of parenchymal transection using BiClamp. In addition, 3 of the 6 patients had a previous upper abdominal operation (2 patients had a hepatectomy and 1 had a left colectomy). Adhesiolysis was also time-consuming in these patients.

The hanging maneuver is an innovative procedure in liver surgery. A hanging tape lifts up the dividing plane, making a straight dividing line. Moreover, raising the liver parenchyma just about to be divided keeps the intrahepatic venous pressure low, which decreases intraoperative blood loss in conventional hepatectomies. The hanging maneuver was also used in the latter part of parenchymal transection in this tape-guided PLH. In contrast to conventional open hepatectomy, raising the dividing plane by the hanging maneuver may not contribute to the decrease of blood loss from intrahepatic veins during parenchymal transection in PLH because there is already a pressure of pneumoperitoneum (set at 8 to 10 mmHg in our hospital). However, the latter part of parenchymal transection is daunting in PLH because it exists deep in the dividing plane. The use of a cotton tape, which not only raises a deeper part of the dividing plane toward the laparoscope, but also makes the dividing plane wide open, makes the latter part of the parenchymal transection much easier.

Only laparoscopic partial hepatectomy and laparoscopic hepatic left lateral sectionectomy had been approved for use in Japan by the Japanese National Health Insurance program at the time this manuscript was submitted. The current indication for PLH in our hospital is restricted to hepatectomy procedures in which a resected specimen is retrieved through a wound of less than 5 cm. True minimally invasive hepatectomy should shorten the lengths of postoperative hospital stays. Otherwise, performing laparoscopic hepatectomy would not be a true minimally invasive practice. We previously reported that laparoscope-assisted hepatectomy through a small incision could not shorten the lengths of postoperative hospital stays compared with conventional open hepatectomies. We introduced PLH to enable us to perform a true minimally invasive hepatectomy. Tape-guided PLH may also be applied to a larger hepatectomy, such as left hepatectomy or posterior sectionectomy. In a larger hepatectomy, a considerable abdominal wall incision is needed to take a resected liver out of the peritoneal cavity, losing the minimally invasive operation of PLH. When it becomes possible to take a relatively large resected specimen out of the peritoneal cavity through a tiny incision, a pure laparoscopic large hepatectomy will become a true minimally invasive operation.

CONCLUSIONS
In conclusion, the procedure presented in this paper enables surgeons to safely perform PLH, not only ensuring an appropriate tumor-free surgical margin, but also making parenchymal transection easier. The only special element needed in this procedure is inexpensive cotton tape.

Author Contributions
Study conception and design: Uchiyama, Morita, Itoh, Takenaka
Acquisition of data: Uchiyama
Analysis and interpretation of data: Uchiyama
Drafting of manuscript: Uchiyama
Critical revision: Morita, Itoh, Takenaka

REFERENCES

Table 2. Surgical Results

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<th>Patient</th>
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HCC, hepatocellular carcinoma; ICC, intrahepatic cholangiocarcinoma.