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Skeletonization and Isolation of the Glissonean and Venous Branches in Liver Surgery With an Ultrasonic Scalpel Technology

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This study describes a novel technique for skeletonization and isolation of Glissonean and venous branches during liver surgery using a harmonic scalpel (HS). Hepatic resections with HS were performed with the skeletonization and isolation technique in 50 patients (HS group). Variables evaluated were blood loss, operative time, biliary leak, and morbidity. The results were compared with 50 hepatic resections that were performed using a previously established technique: Cavitron ultrasonic surgical aspirator with electric cautery, ligatures, and hemoclips (NHS group). The HS group had shorter total operative times (285 versus 358 minutes; $P = 0.01$), less blood loss (389 versus 871 mL; $P = 0.034$), and less crystalloid infusion (2744 versus 3299 mL; $P = 0.027$) compared with the NHS group. Postoperative liver function and complication rates were similar when comparing the two groups. These data demonstrate that HS is a simple, easy, and effective instrument for the skeletonization and isolation of vessels during liver transection.

Key words: Liver resection – Ultrasonic scalpel – Skeletonization – Cavitation effect

Various devices are available for liver transection, but the availability of comparative data for transection techniques is limited by the diversity of operative procedures. Clamp crushing (CC) and a Cavitron ultrasonic surgical aspirator are widely used for splitting the liver parenchyma,[1,2] and hemostasis is achieved by bipolar coagulation, ligatures, or hemoclips. Various coagulating devices, such as Ligasure,[3] Tissuelink,[4] and the Harmonic Scalpel (HS),[5–7] have recently been developed to aid in liver splitting. The choice of instrument is often based on individual surgeon preference. Higami *et*

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al[8,9] described a novel technique to skeletonize and harvest the internal thoracic artery with the HS, and the present study capitalizes on their experience to describe a unique method to skeletonize and isolate the Glissonean and venous branches using an HS.

Patients and Methods

Beginning in January 2004, hepatic resections were performed in the Department of Surgery, School of Medicine, Showa University, Tokyo, Japan, using an HS for liver transection. In previous years, liver transection was performed without the HS.

The skeletonization and isolation technique with the HS was used for 50 consecutive liver resections (HS group). Results of these procedures were compared with those of another group of patients with similar demographic and pathologic features who underwent liver resection without the HS (NHS group). This latter group of patients was selected from a list of consecutive patients who underwent surgery prior to the availability of the HS technique. The adequacy of the remnant liver for major resections was determined by an estimate on computed tomographic volumetry with an indocyanine green clearance test.

Patients were monitored for the development of postoperative fluid collections and/or biliary fistulas. Bile leakage was suspected by evaluating drainage fluid color and by assaying bilirubin level into the drainage fluid. A total bilirubin level into the drainage fluid of >5 mg/dL in patients with normal serum bilirubin value was considered diagnostic of bile leakage. Grading of bile leakage after hepatic resection was assessed according to the International Study Group of Liver Surgery definition.[10]

Surgical technique

Laparotomy was performed through a right subcostal incision and a midline incision. Following laparotomy and exploration for intra-abdominal metastasis, the liver was mobilized in the standard fashion. Intraoperative ultrasound was performed to decide the extent of disease and to plan the parenchymal transection plane. Stay sutures were placed along the plane of intended transection. The liver tissue was divided using the HS (output level, 3) with the active edge of the blade turned downward. Parenchymal tissue was easily removed by moving the HS along the length of the Glissonean branch to lightly sweep tissue away and to expose the Glissonean branch (Fig. 1a and 1b). The HS was moved quickly along several centimeters of the parenchymal tissue using light touch along the Glissonean branch to safely and quickly skeletonize the Glissonean branches. Branch exposure is confirmed visually. Glissonean and venous branches up to about 3 mm in diameter were occluded and divided by ultrasonic protein coagulation without injury (Fig. 1c and 1d). Branches can be separated by complete protein coagulation in 3 to 4 seconds with average force compression, before being spontaneously divided with complete hemostasis. No clip was needed for Glissonean branches and veins less than 3 to 4 mm in diameter. Glissonean branches from 3 to 5 mm in diameter were controlled with titanium clips and divided sharply. A few larger Glissonean branches and hepatic vein that were encountered were dissected using the HS (Fig. 1e and 1f), controlled with 3-0 vicryl ties in continuity, and divided sharply.

Statistical analysis

Values are expressed as means ± SD. Statistical analysis was performed by *t*-tests using Stat View (SAS Institute, Cary, North Carolina). All *P* values less than 0.05 were considered to indicate statistical significance.

Results and Discussion

The distribution of demographic and pathologic variables was equivalent between the two patient groups (Table 1). The overall mean blood loss was lower in the HS group (285 mL; range, 45–615 mL) than in the NHS group (358 mL; range, 190–600 mL). The skeletonization and isolation technique in the HS group could be performed precisely and easily for dissection of the Glissonean branches and hepatic vein. Operation time with this technology (skeletonization and isolation technique) for hepatectomies was shortened to an average of 73 minutes in subsequent liver resections compared with time in the NHS group (Table 2).

There was no significant difference in the number of complications when comparing the two study groups (Table 3). There were no perioperative deaths in either group, and no patients required re-exploration. One patient in the HS group and one patient in the NHS group required percutaneous drainage for fluid collection and/or grade A bile leakage. In each case, the collection or fistula

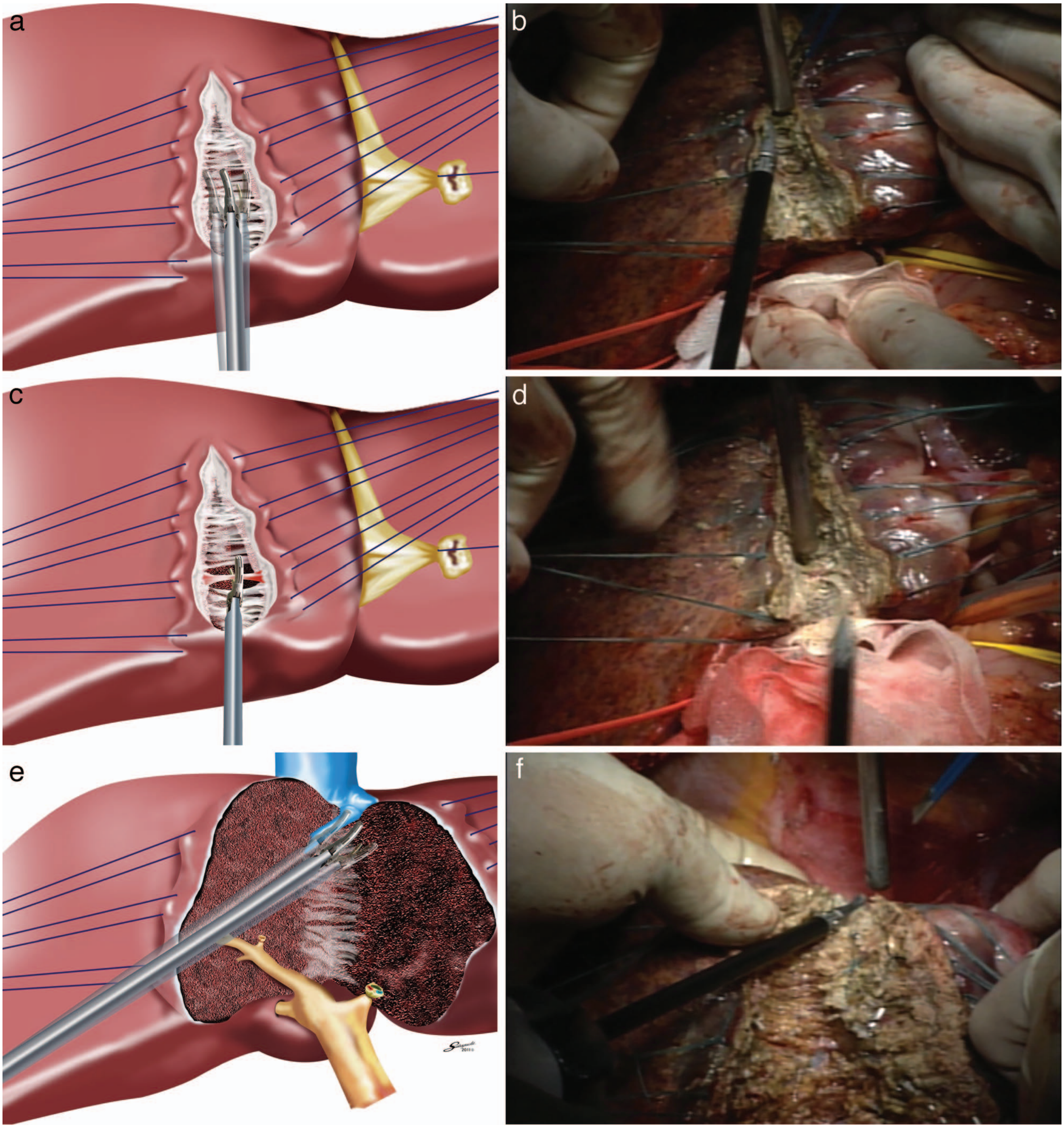

Fig. 1 (a) Schema of panel b. (b) The liver tissue is divided using the HS (output level, 3) with the active edge of the blade turned downward. Parenchymal tissue is easily removed by moving the ultrasonic scalpel along the length of the Glissonean branch to sweep away the tissue and to expose the Glissonean branch. (c) Schema of panel d. (d) When the branch is exposed and confirmed visually, Glissonean and venous branches up to 3 mm in diameter are occluded and divided by the HS via ultrasonic protein coagulation. (e) Schema of panel f. (f) The hepatic vein is carefully dissected using the HS. Importantly, the contact time of the HS is set to less than 0.5 seconds, and the HS is moved lightly and quickly along less than 1 cm of the vessel.

Table 1 Patient characteristics and pathologic variables

Patient characteristics	HS group (n = 50)	NHS group (n = 50)
Median age, y (range)	69.7 (46–84)	67.9 (37–85)
Male/female, n	29/21	33/17
Background liver status: normal/ chronic hepatitis/cirrhosis, n	26/8/16	25/10/15
Histology, n		
Hepatocellular carcinoma	18	19
Cholangiocarcinoma	7	7
Colorectal carcinoma	15	17
Gastric carcinoma	2	3
Other metastatic liver tumor	6	1
Benign	2	2
Other	0	1
Median no. of tumors (range)	2.04 (1–10)	1.94 (1–9)
Median size of largest tumor, mm (range)	39.1 (8–82)	42.1 (8–102)

resolved following a short course of percutaneous drainage and, when indicated, antibiotic therapy.

Several techniques for liver transection have been used with the goal of reducing intraoperative blood loss; these include the CC,[1,11–13] ultrasonic dissector (UD),[2,14,15] hydrodissection,[16] laser systems,[17] saline-linked radiofrequency sealers,[4] and HS.[5–7] The UD and CC techniques appear to be the most frequently used. Several recent studies have reported that there were no significant differences in intraoperative bleeding and operating time when comparing the CC technique and those using other devices.[11–13,18] However, the CC technique requires more specialized technical training to accomplish a safe operation compared with other devices used for liver transection. The UD, despite being more costly and time-consuming than CC, has gained wide acceptance because of the potential to reduce bleeding during liver resection. Indeed, Fan *et al*[2] reported a 30% reduction in blood loss after changing techniques from CC to UD. One limitation of the UD technique is that blood vessels and biliary tract branches need to be clipped or sutured to achieve complete hemostasis and biliary stasis during dissection. The HS device provides both effective crush and coagulation functions during liver transection. The present study demonstrated that the HS is a safe and simple instrument for use during skeletonization and isolation of vessels during liver parenchymal transection.

The HS uses ultrasonic energy to disrupt tissues by cavitation. Using the cavitation effect, the Glissonean branches and vein were easily skeletonized and isolated. Moreover, the HS uses high-frequency mechanical energy to produce controlled and precise incision and hemostasis.[19] Because this instrument can produce simultaneous hemostasis and coagulation with minimal injury to surrounding

Table 3 Morbidity of patients undergoing liver resections[a]

Patient characteristics	HS group (n = 50)	NHS group (n = 50)
Death	0	0
Wound infection	2	3
Pleural effusion	5	4
Chest infection	1	1
Bile leakage (ISGLS grade A)	1	1
Abdominal abscess	2	1
Postoperative bleeding	1	1
Persistent ascites	1	2
Hyperbilirubinemia	1	0

ISGLS, International Study Group of Liver Surgery.

[a]Values are given as number of patients. Overall complication rate was 28% in the HS group and 26% in the NHS group.

Table 2 Operative and anesthetic variables

Variables	HS group (n = 50)	NHS group (n = 50)	*P*
Extent of resection, n			
Wedge	24	25	NS
Segmentectomy and subsegmentectomy	16	15	NS
Hemihepatectomy or more	10	9	NS
Median total operative time, min (range)	285 (45–615)	358 (190–600)	<0.01
Median warm ischemic time, min (range)	63 (15–225)	76 (30–165)	NS
Median estimated blood loss, mL (range)	389 (45–1100)	871 (220–2670)	<0.01
Median crystalloid infusion, mL (range)	2744 (930–6250)	3299 (1450–5950)	0.016
Blood transfusion infusion			
Patients, n (%)	2 (4)	10 (20)	
Median infusion, mL (range)	340 (280–400)	753 (130–2240)	NS
Tumor exposure, n			
Yes	4	3	NS
No	46	47	NS

NS, not significant.

tissues, this approach theoretically offers considerable advantages over electric coagulation. This study is the first report to describe the use of HS for skeletonization and isolation of vessels during liver transection.

The present study demonstrated that there were no significant differences between the HS and NHS groups in terms of postoperative hepatic function or complications. In particular, rates of bile leakage were similar in each group. Therefore, these data indicate that the HS enables safe transection of the liver. Use of the HS alone has previously been associated with a significant increase in the incidence of postoperative bile leaks.[18] Therefore, particular care must be taken to assure that the HS fully isolates and cuts the vessel branches. We typically use the HS to cut and coagulate Glissonean branches with diameters less than 2 to 3 mm.[20]

In this study, significantly less blood loss was seen in patients undergoing liver resection with the HS under inflow occlusion compared with the NHS group (Table 2). Because the HS has the ability to both coagulate and dissect intrahepatic structures with high-frequency mechanical energy, hemorrhage after release of the inflow occlusion was also minimal and comparable with that in the NHS group. These observations support the safety of the HS. Although patients in the NHS group theoretically undergo division of the liver parenchyma without vessel injury, bleeding from smaller vessels does occur, impairing optimal visibility of the transection plane. Similar experiences have been reported by others, with Aloia *et al*[19] demonstrating that in two well-matched patient groups undergoing liver resection, addition of the HS to UD for parenchymal transection resulted in reduced operating time. Moreover, Aloia *et al*[19] account for the shorter operating times seen in the HS group in several phases of the operation.

The present study evaluated postoperative mortality and morbidity in the HS and NHS groups. Rates of minor and major complications were not significantly different between the two groups. However, bile leaks remain a challenging complication, occurring in 5% to 14% of patients undergoing hepatectomy. Kim *et al*[21] demonstrated that use of the HS was associated with a significant increase in the incidence of postoperative bile leaks. The present data suggest that both techniques can achieve safe liver resection with similar complication profiles and a minimal risk of bile leakage, but surgeons must be cautious during liver parenchymal transection when using the HS for dissection of the Glissonean branches.

In conclusion, the HS is a simple, safe, and minimally invasive method for skeletonization and isolation of the Glissonean branches and hepatic vein.

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