Cohort study

Usefulness of Vessel-sealing Devices Combined with Crush Clamping Method for Hepatectomy: A Retrospective Cohort Study

Running title: Usefulness of sealing devices for hepatectomy

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Abstract

Background: Blood loss during resection of the hepatic parenchyma in hepatectomy can be minimized using vessel-sealing (VS) devices. Some sealing devices were retrospectively compared to evaluate the efficacy of each device for controlling blood loss, transection time and postoperative complications in hepatectomy as a cohort study.

Methods: Between 2005 and September 2012, hepatectomy was underwent in 150 patients using one of three types of LigaSure™ (Dolphin Tip Laparoscopic Instrument, Precise or Small Jaw) or the Harmonic Focus or Ace ultrasonic dissecting sealer. Results were compared to crush-clamping alone as the control method by the historical study (n=81).

Results: Irrespective of the vessel-sealing device used for underlying chronic hepatitis, blood loss, blood transfusion rate, operating time and transection time were significantly reduced in the VS group compared with controls ($p<0.05$). Rates of postoperative bile leakage and intra-abdominal abscess formation were significantly lower in the VS group than in controls ($p<0.05$). Comparing devices, LigaSure Small Jaw and Harmonic Focus showed lower blood loss, shorter transection time and reduced rates of post-hepatectomy complications, in turn resulting in shorter hospital stays ($p<0.05$). Tendencies toward uncontrolled ascites and bile leakage were only concern with the use of Harmonic Focus. Satisfactory surgical results were achieved using the sealing device for laparoscopic hepatectomy.

Conclusions: The use of energy sealing devices improves surgical results and avoids hepatectomy-related complications. Adequate use of vessel sealers is necessary for safe and rapid completion of hepatic resection.

KEYWORDS: hepatectomy; vessel sealing; crush clamping; bloodless: morbidity; cohort study

Introduction

Minimization of blood loss during hepatic parenchymal transection remains a concern, despite recent advances in surgical techniques and perioperative management for hepatic resection.[1] The increased amount of blood loss and related transfusion are risk factors for morbidity and mortality in patients who undergo hepatectomy. [2] The crush clamping method for hepatic parenchymal transection is well-known and widely applied, offering a simple approach with flexible control.[3,4] We have used this technique for the past 15 years and, however, small remnant branches must be tied using numerous knots, which may require a relatively long time. To reduce operative risks, further improvements in surgical techniques and/or hemostatic devices are needed for hepatic transection in patients with both normal and diseased livers.[5] The latest surgical devices for hemostasis have been applied in liver surgery in recent years.[5-9] Kristinn et al. recently reported that the LigaSure, using powerful bipolar electric thermal energy, is more efficient than ultrasonic shears for hepatic resection in a porcine model.[7] To overcome the limitations of the classical crush clamping method, we have begun to apply a combination technique with vessel-sealing devices in hepatic resection since 2008. We have already provided a preliminary report of the usefulness of such a combination method using the *LigaSure* Precise™, a prototype device offering reductions in blood loss, transection time and risk of morbidity.[10] Over the past several years, the utility of vessel-sealing devices used at our institute has changed. We hypothesized that the operative record should be improved by using the powerful and fast hemostatic devices. However, no full comparisons of each method have yet been reported, and the clinical advantages and disadvantages of each method need to be clarified.

To this end, the present cohort study retrospectively examined patient demographics, surgical records and patient outcomes, comparing the results between conventional crush clamping,

various type of LigaSure vessel-sealing device and an ultrasonic coagulator system in patients who underwent hepatectomy in recent years.

Materials and methods

Patients

We retrospectively and historically examined 267 patients with liver disease who underwent hepatic resection in our institute between 2005 and September 2012. The present cohort setting compared patient demographics, parameters of preoperative liver function, background liver status, surgical records and postoperative course according to the extent of hepatectomy between conventional crush clamping (control group, treated between 2004 and 2008; n=118) and vessel sealing (VS group, treated between 2008 and 2012; n=149). All patients' in-hospital data was consecutively collected during these follow-up periods. There were no patient selection or matching criteria, and all patients were enrolled for the present study. Informed consent for data collection and use of hemostatic devices was obtained from each patient prior to enrolment. The study design was approved by the ethics review board at our institution. Data were retrieved from both anesthetic and patient charts by the NUGSBS database.

Operative procedures

In the case of open laparotomy, the procedure included routine clamping of the hepatoduodenal ligament to occlude total inflow to the liver during transection. It also included the use of the forceps crush clamping method[4] and an ultrasonic dissector (USU MH-207; Olympus, Tokyo, Japan) around the major vessels. Using a Kelly clamp, the hepatic parenchyma was gently crushed and confirmation was obtained that the remnant vessels and tiny vessels (≤2 mm in diameter) were divided by the vessel sealers.[10, 11] Larger vessels (≥3 mm in diameter) were tied using absorbable braid (Ethicon, Somerville, NJ). Glissonian branches near the secondary trunk were also tied. The isolated large hepatic vein was ligated by Endopath-Endocutter ETS-Frex 35 (staple load; 3.0 × 35 mm, white cartilage; Ethicon Endo-surgery, Johnson & Johnson Company, Somerville, NJ).[12]

The present series used three types of LigaSure™ system (Surgical Solutions Group, Boulder, CO): LigaSure Precise™ Instrument (LS1200); LigaSure™ Small Jaw Instrument (LF1212); and LigaSure™ Dolphin Tip Laparoscopic Instrument (LS1500). Characteristics of blade size, style, sealed width and length are compared in Fig. 1 and Table 1. LigaSure V was used for both open and laparoscopic procedures. With LigaSure Precise™ Instrument, sealed vessels were cut using fine scissors by the first assistant operator. [10, 13, 14] The other two devices had a built-in cutting function. The power supply level was fixed at level 2. The LigaSure™ vessel-sealing generator was the new ForceTriad™ Energy platform, which includes a hand and foot switch (Valleylab), as a full-featured radiofrequency energy system allowing precise automatic management of energy and desired tissue effect in Fig. 2.

Other types of vessel sealer were Harmonic Focus® Curved Shears (ultrasonic coagulator dissector; Ethicon Endo-surgery) for open laparotomy [11] and Harmonic Ace® Curved Shears (Ethicon Endo-surgery) for laparoscopic hepatectomy. [15-17] Coagulation and dissecting power is equivalent to Harmonic Focus and Ace. Characteristics of blade size, style, sealed width and length are compared in Fig. 1 and Table 1. This device includes an automatic cutting function during coagulation. The power supply level was fixed within the range of 3 to 5. A Harmonic Device Generator 300 system was operated using a hand switch (Ethicon Endo-surgery), as a full-featured high-frequency mechanical energy system. The sealing time is again only a few seconds, providing fast, powerful sealing in Fig. 2. [17]

Decisions on which instrument to use for open laparotomy were made based on the judgment of the operator during the period of the present study (Operator A.N., T.A. and S.T.), which was a potential bias in the present study. The vessel sealer was clamped along the hepatic vein and sealed the branched veins without clipping or ligation.[10] Any bleeding site and macroscopically detected bile leakage points in the cut plane were sutured using absorbable 4-0 monofilament polydioxanone (PDS)-II suture (Ethicon).

In the present study, the patient demographics, surgical records and postoperative outcomes after hepatectomy were compared between the control group without vessel sealers and the vessel sealer group. Furthermore, the vessel sealer group was subdivided by the groups of each vessel sealing instrument. Such a clinical parameter was often examined to clarify the usefulness of surgical devices.

Statistical analysis

All continuous data are expressed as mean±standard deviation. Data of different groups were compared using one-way analysis of variance. The χ^2 test was used for comparisons of categorical variables. Differences between groups were analyzed using Fisher's exact test and Scheffe's multiple comparison test, which was the most sensitive analysis. A two-tailed *P* value of less than 0.05 was considered significant. SPSS Statistics version 18 software (IBM, Armonk, NY) was used in all statistical analyses.

Results

Patient data

The control group (n=118) underwent limited resection in 38 patients (32%), segmentectomy or sectionectomy in 43 (21%), hemihepatectomy or more extensive resection in 31 (36%), central bisegmentectomy in 1 (1%) and trisegmentectomy in 5 (10%). Child-Pugh classification was A in 112 patients (95%) and B in 6. In the VS group (n=149), limited resection was performed in 56 patients (including laparoscopic limited resection in 15), segmentectomy or sectionectomy in 45 (including laparoscopic lateral segmentectomy in 6), hemihepatectomy or more extensive resection in 42 (36%), central bisegmentectomy in 3 (1%) and trisegmentectomy in 2 (10%). Child-Pugh classification was A in 147 patients (99%) and B in 2. We compared data between the two groups according to the extent of hepatectomy as: 1) smaller hepatectomy than sectionectomy (81 patients in the control group; 81 patients in the VS group, including LigaSure V in 5 patients, LigaSure Precise in 36, LigaSure Small Jaw in 30 and Harmonic Focus in 10); 2) hemihepatectomy or more extensive resection (37 patients in the control group; 47 patients in the VS group, including LigaSure Precise in 21, LigaSure Small Jaw in 12 and Harmonic Focus in 14); and 3) laparoscopic or laparoscopy-assisted hepatectomy using VS in 21 patients (including LigaSure V in 11 patients, LigaSure Precise in 5, and Harmonic Ace in 5).

Surgical records

Table 2 shows the clinical data of patients who underwent smaller hepatectomy. The prevalence of chronic viral hepatitis was significantly greater in the VS group (35%) than in the control group (15%) ($p<0.05$). The prevalence of hepatocellular carcinoma (HCC) tended to be greater in the VS group (48%) than in the control group (37%), but no significant difference was identified. Operative blood loss and use of red cell transfusion were significantly less

frequent in the VS group than in the control group ($p<0.01$). Total operating time and hepatic parenchymal transection time were significantly shorter in the VS group than in the control group ($p<0.05$). The prevalence of bile leakage was significantly lower in the VS group than in the control group ($p<0.05$), while the prevalence that of associated intra-abdominal infection tended to be lower in the VS group than in the control group, although no significant difference was evident. The duration of hospitalization was significantly shorter in the VS group than in the control group ($p<0.01$). Patient demographics, liver function, surgical records, post-hepatectomy morbidity and duration of hospitalization did not differ significantly between each device.

Table 3 shows the clinical data of patients who underwent major hepatectomy. Prevalence of obstructive jaundice or biliary tract carcinomas tended to be greater in the VS group that in the control group, but no significant difference was apparent. Operative blood loss and blood transfusion were significantly lower in the VS group than in the control group ($p<0.05$). Hepatic parenchymal transection time tended to be shorter in the VS group than in the control group, but no significant difference was seen. The prevalence of uncontrolled ascites was significantly lower in the VS group than in the control group ($p<0.05$). The duration of hospitalization was significantly shorter in the VS group than in the control group ($p<0.01$). Patient demographics and liver function did not differ significantly between devices. Operative blood loss was significantly lower in the LigaSure Precise and Small Jaw groups than in the Harmonic group ($p<0.05$). Hepatic parenchymal transection time in the LigaSure Small Jaw group was significantly lower than those in the LigaSure Precise group and the control group ($p<0.05$). The prevalence of uncontrolled ascites was significantly higher in the Harmonic group than in other groups ($p<0.05$). Prevalence of bile leakage and intra-abdominal infection were significantly lower in the LigaSure Precise group than in other groups. Duration of

hospitalization was significantly shorter in the LigaSure Precise group than in the Harmonic group ($p<0.05$).

Table 4 shows the clinical data of patients who underwent laparoscopic minor hepatectomy. Patient demographics and liver function did not differ between groups. In the VS group, operative blood loss tended to be lower than in the control group, although no significant difference was seen. Hepatic parenchymal transection time was significantly shorter in the VS group than in the control group ($p<0.05$). Post-hepatectomy complications were not observed in all patients, and no significant difference in prevalence was identified between VS and control groups. The duration of hospitalization was significantly shorter in the VS group than in the control group ($p<0.01$). HCC was not observed in the Harmonic group, but was seen in other LigaSure groups ($p<0.05$). Operative blood loss tended to be lower in the LigaSure Precise group than in other groups, but no significant difference was apparent. Total operation time was significantly lower in the LigaSure Precise group than in the LigaSure V group ($p<0.05$) and hepatic parenchymal transection time was significantly shorter in the LigaSure Precise group than in the Harmonic (Ace) group ($p<0.05$). Post-hepatectomy complications were not observed in all patients who underwent laparoscopic hepatectomy.

Discussion

The LigaSure system comprises various instruments for open and laparoscopic use (http://www.ligasure.com/ligasure/pages.aspx?page=Products)[13, 14, 16, 18, 19] and the Harmonic system also comprises various instruments (http:// www.jnj.com/ connect/ healthcare-products/ recent).[6, 11, 15, 16] Since our preliminary report regarding the efficacy of the LigaSure Precise™ for hepatic resection, [10] the new LigaSure Small Jaw and Harmonic Focus devices have been developed. [11] We have therefore been using various devices for hepatectomy, as in the present study. Other powerful instruments such as advanced diathermy devices, bipolar coagulators, the TissueLink dissecting sealer and so on have been recently been released worldwide.[4, 9, 20-22] We regret that randomized selection of devices could not be performed in the present series, which might thus be influenced by some selection bias. Each device used in the present study offered powerful sealing activity, [10, 11, 16, 19] but the length or width of the blades did not always match the narrow spaces encountered during hepatic parenchymal transection. The shape of the area between the handle and blade of the LigaSure and Harmonic coagulator resembles a small forceps, [11, 17] offering high grasping ability and various grip positions that are feasible in a wide range of situations. Since the thermal range around the grasping blade is quite limited within 1-2 mm, thermal damage to the deep cut surface of the liver can be avoided. [16] (Fig. 3) Based on the forceps-like configuration, the tip of the blade is easy to widely palpate compared with other instruments designed with a long shaft for laparoscopic use. Compared to the LigaSure device, an ultrasonic dissector may produce more heat damage.[6,16] Kim et al. reported a significant increase in bile leakage when using the ultrasonic dissector,[23] although another study showed no major postoperative complications.[6,11] The differences creating advantages or disadvantages for each device must therefore be clarified to achieve reliable, safe hepatic transection.

In the present study, blood loss and related need for red cell transfusion, the time required for transection of the hepatic parenchyma and related operating time were shorter in the VS group than in controls, as expected from the pilot study[10] and other reports. [8, 11, 13-15, 18, 19] Nevertheless, at smaller hepatectomy series, the prevalence of underlying chronic hepatitis was higher in the VS group and differences in the above-mentioned parameters were significantly better in the VS group. The usefulness of VS has thus been highlighted. Although crush clamping was often difficult in cirrhotic liver, hard fibrotic tissues could be sufficiently coagulated and cut simultaneously using high-energy devices.[24,25] With respect to postoperative morbidity, VS could also prevent bile leak and associated intra-abdominal infection. As a result, the duration of hospitalization could be significantly shortened in the VS group due to better results for surgical data and morbidity As bile leakage sometimes causes major problems leading to prolonged hospitalization,[26] control of bile leakage using VS provides a great many clinical benefits. In the large hepatectomy series, surgical records from the VS group were also better, even though the prevalence of biliary tract carcinoma was higher in the VS group. In the case of biliary carcinoma, more complicated hepatectomies such as caudate lobe resection or combined vascular resection and reconstruction were necessary, which might have led to longer operating times and greater blood loss. However, surgical records for patients with hilar bile duct carcinomas in the VS group tended to be better than expected and the morbidity of ascites from the lymphatic duct could be controlled using VS. As a result, clinical benefits with shorter duration of hospitalization could be obtained along with successful minor hepatectomy in the present series.

We examined surgical outcomes in patients who underwent laparoscopic minor hepatectomy in this study. In cases of laparoscopic or laparoscopy-assisted hepatectomy with small incision laparotomy, use of VS is always necessary. [19, 27, 28] In the present series, surgical outcomes were quite good, without any post-hepatectomy complications and limited blood loss, as

described in other reports. [27, 28] The sealing capacity of energy devices would be clarified by these results as Pringle's maneuver, as the in-flow occlusion technique was not applied in such cases.[29]

By comparison with each device, the forceps-style LigaSure for open use was preferentially applied in our series, although the bias of disease selection might not have been marked. The forceps-style LigaSure showed better surgical records and patient outcomes in patients who underwent major hepatectomy, although differences in surgical records between each device were not observed in patients with minor hepatectomy. Production of uncontrolled ascites and bile leakage by ultrasonic coagulators as Harmonic Focus or Ace remained a concern, because such complications would result in a longer hospital stay.[23] In our experiences during hepatectomy, bile leakage has often been seen in the transected cut plane. When we noticed bile leakage intraoperatively, leakages could be repaired by suture. Ultrasonic coagulating devices might allow faster cutting with hemostasis due to high energy, but sealing the lymphatic duct and bile duct would be insufficient using fast speed sealing. Care must be taken to carefully seal the parts of the lymphatic duct and Glissonian pedicle when the ultrasonic coagulator was used. Small Jaw showed the best surgical records and outcomes in general because a cutting function was added. Although selection bias remains, LigaSure Small Jaw would be recommended for use in open hepatectomy in comparison with LigaSure Precise or V based on the present results. By making comparisons with the latest forceps-style devices, LigaSure Small Jaw and Harmonic Focus, we could not clarify superiority between devices, as both utility and efficacy were similar. As described above, ascites and bile leakage after hepatectomy were only concerns when using the Harmonic Focus. To the best of our knowledge, such comparisons between devices have yet to be reported.

In laparoscopic hepatectomy, LigaSure Precise tended to show better surgical records in comparison with Harmonic group in the present study. LigaSure Precise is basically an open

use instrument, and so was used for laparoscopy-assisted hepatectomy with minimal incisions.[30] The LigaSure V and Harmonic Ace were usually used in laparoscopic hepatectomy,[7, 15, 27, 28] so we also clarified herein the usefulness of VS in our series. The present study was a retrospectively cohort study, in which the present study design might provide some bias in results. Therefore, it is necessary to design a prospective randomized study in each subgroup in the suture step.

In conclusion, the latest vessel sealer is very useful for open and laparoscopic hepatectomy for hepatic parenchymal transection in comparison with the conventional procedure, due to the minimization of blood loss and the shortening of transection time, resulting in better postoperative outcomes in hepatectomy. In vessel sealers, the latest forceps-style devices are better suited to open use. In laparoscopic hepatectomy, use of a vessel sealer is essential and surgical outcomes are quite satisfactory.

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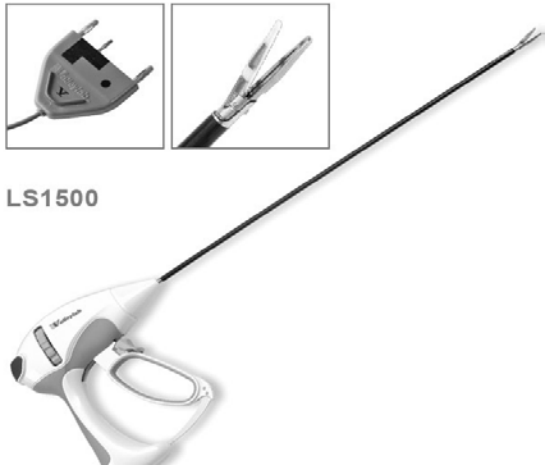
FIGURE LEGENDS

Figure 1. Comparison of function between three types of LigaSure™ system, LigaSure Precise™ Instrument (LS1200); LigaSure™ Small Jaw Instrument (LF1212); and LigaSure™ Dolphin Tip Laparoscopic Instrument (LS1500). Comparison of function of the ultrasonic coagulators; Harmonic Focus® Curved Shears for open use and Harmonic Ace® Curved Shears as a laparoscopic instrument were also compared.

Figure 2. Generators of energy devices.

Figure 3. Cut surface of parenchymal transections by A) LigaSure™ and B) Harmonic™.

Figure 1



LigaSure™ V

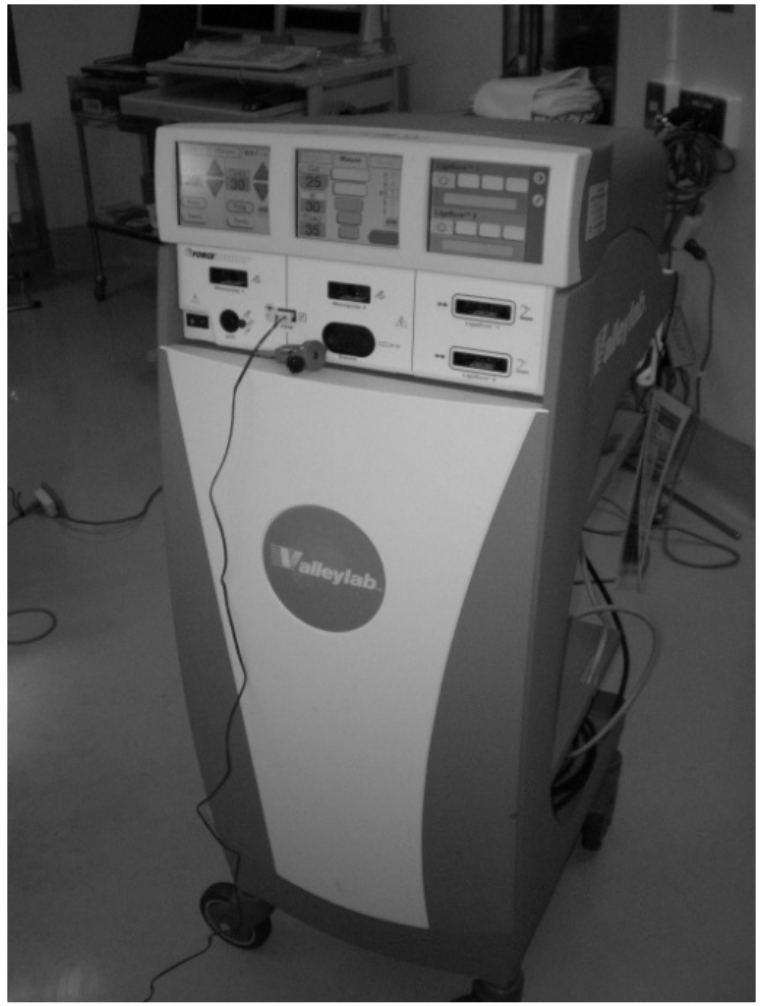
LigaSure Precise™

LigaSure™ Small Jaw

Harmonic Ace™

Harmonic Focus™

Figure 2



ForceTriad™ energy platform

Harmonic device generator 300 system

Figure 3

A)

B)

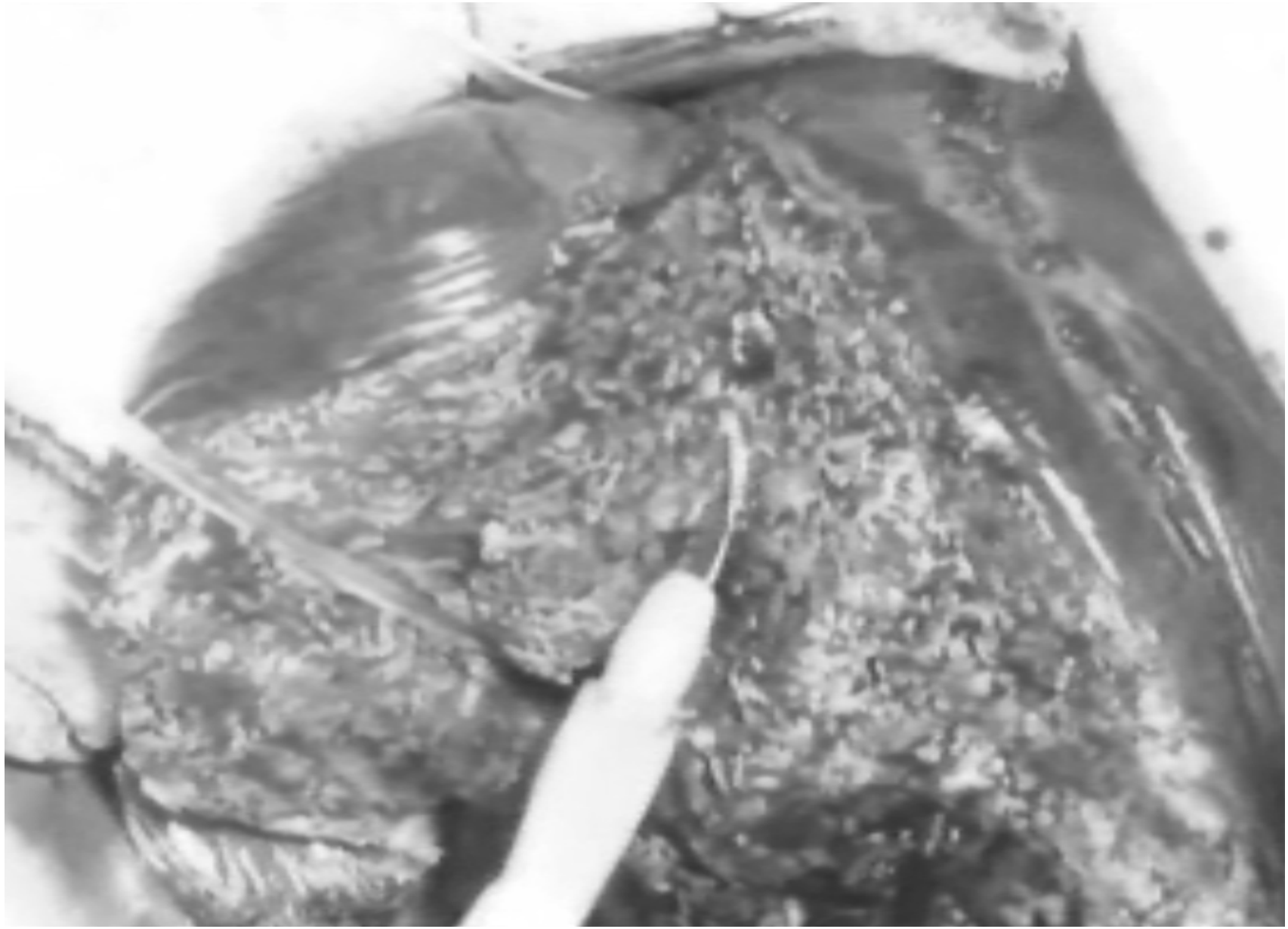


Table 1 Shape and function of LigaSure products and harmonic scalpels

	Seal length (mm)	Seal width (mm)	Cut length (mm)	Used situation
LigaSure V	18-19.5	4.6-5	12-17.8	Laparoscopic use
LigaSure Precise	16.5	3	nil	Open use for narrow part
LigaSure Small Jaw	16.5	4	14.7	Open use for narrow part
Harmonic Focus	16	1.4	16	Open use for narrow part
Harmonic Ace	12	1.4	12	Laparoscopic use

Table 2 Comparison of data from the control group and vessel-sealer groups for patients who underwent limited resection, segmentectomy or sectionectomy.

	Control group (n=81)	VS group (n=81)	*p value*	LigaSure V (n=5)	LigaSure Precise (n=36)	LigaSure Small Jaw (n=30)	Harmonic UC (n=10)	*p value*
Age (years)	66±12	67±12	*.344*	667±13	67±13	65±12	71±6	
Gender (male/female)	58/23	56/25	*.742*	3/2	24/12	23/7	5/5	*.339*
Background liver condition								
Normal/chronic hepatitis/cirrhosis/jaundice	54/12/14/1	41/28/12/0	*.0002*	4/0/1/0	15/14/7/0	16/13/1/0	7/1/2/0	*.243*
Liver disease								
HCC/ICC/liver metastasis/BC/Others	30/1/38/7/5	39/6/27/7/2	*.084*	1/1/3/0/0	21/1/11/1/2	14/2/12/2/0	2/2/1/4/1	*.670*
Preoperative liver function								
ICGR15 (%)	14.6±9.3	15.5±10.6	*.762*	13.5±10.6	14.5±9.1	14.6±9.3	19.8±7.8	
Surgical records								
Blood loss (ml)	1040±984	613±544	*.0004*	520±99	703±619	560±474	534±445	
Red cell transfusion rate (No/Yes)	60/21	75/6	*.0007*	4/1	31/5	30/0	10/0	*.647*
Total operation time (minutes)	418±144	346±122	*.0016*	294±79	345±113	345±128	371±144	
Transection time (minutes)	56±20	43±28	*.045*	48±22	58±33	45±17	31±28	

Outcome								
Hospital death (No/Yes)	80/1	80/1	*1.0*	5/0	36/0	29/1	10/0	*.665*
Hepatectomy-related complications (No/Yes)	73/8	69/12	*.419*	4/1	27/9	28/2	10/0	*.105*
Uncontrolled ascites* (No/Yes)	74/7	70/11	*.403*	4/1	28/8	28/2	10/0	*.126*
Bile leakage (No/Yes)	71/10	79/2	*.029*	5/0	35/1	30/0	9/1	*.319*
Intraabdominal abscess formation (No/Yes)	73/8	79/2	*.080*	5/0	36/0	28/2	10/0	*.350*
Hospital stay (days)	24±12	16±12	*<.0001*	15±11	18±17	14±6	19±9	

Continuous data are mean±SD or categorical data are number of patients

*after 1-week of treatment with diuretics

UC; ultrasonic coagulator, ICGR15: Indocyanine green retention rate at 15 minutes, HCC: hepatocellular carcinoma,

ICC: intrahepatic cholangiocellular carcinoma, BC: biliary tract carcinoma

Table 3 Comparison of data from the control group and vessel-sealer groups for patients who underwent hemihepatectomy or more extended hepatectomy.

	Control group (n=37)	VS group (n=47)	*p value*	LigaSure Precise (n=21)	LigaSure Small Jaw (n=12)	Harmonic UC (n=14)	*p value*
Age (years)	68±11	67±14	*.414*	68±11	71±9	64±20	
Gender (male/female)	24/13	30/12	*.671*	12/9	8/4	10/4	*.670*
Background liver condition							
Normal/chronic hepatitis/cirrhosis/jaundice	21/13/2/1	20/13/2/12	*.082*	7/9/1/4	6/3/0/3	7/1/1/5	*.381*
Liver disease							
HCC/ICC/liver metastasis/BC/Others	14/8/5/7/3	12/8/5/16/6	*.078*	8/2/1/7/3	3/4/1/3/1	1/2/3/6/2	*.349*
Preoperative liver function							
ICGR15 (%)	13.2±8.8	12.2±5.8	*.803*	12.0±6.0	12.9±6.4	11.8±5.2	
Surgical records							
Blood loss (ml)	2093±1458	924±723	*.0054*	1029±637*	952±567*	1410±1010	
Red cell transfusion rate (No/Yes)	18/19	35/12	*.032*	15/6	7/5	10/4	*.703*
Total operation time (minutes)	656±202	587±192	*.169*	575±180	623±157	578±241	
Transection time (minutes)	47±19	43±17	*.055*	44±23	40±8#	42±10	

Outcome							
Hospital death (No/Yes)	35/2	46/1	*.580*	21/0	12/0	13/1	*.299*
Hepatectomy-related complications (No/Yes)	29/8	33/14	*.552*	19/2	8/4	6/8	*.010*
Uncontrolled ascites* (No/Yes)	30/7	45/2	*.039*	19/2	10/2	6/8	*.0048*
Bile leakage (No/Yes)	32/5	42/5	*.911*	21/0	10/2	10/4	*.041*
Intraabdominal abscess formation (No/Yes)	30/7	41/6	*.638*	21/0	9/3	11/3	*.060*
Hospital stay (days)	36±23	24±13	*.0096*	19±6†	24±18	27±12	

For abbreviations, see Table 2

***;** $p<0.05$ *vs.* the *Harmonic group*. [#]; $p<0.05$ *vs.* the *LigaSure Precise group*. [†]; $p<0.05$ *vs.* the *Harmonic UC group*.

Table 4 Comparison of data from the control group and vessel-sealer groups for patients who underwent laparoscopic limited resection and lateral segmentectomy.

	Control group (n=81)	Laparo VS group (n=21)	*p value*	LigaSure V (n=11)	LigaSure Precise (n=5)	Harmonic UC (n=5)	*p value*
Age (years)	66±12	64±11	*.414*	65±11	67±13	58±9	
Gender (male/female)	58/23	14/7	*.671*	7/4	3/2	5/0	*.170*
Background liver condition							
Normal/chronic hepatitis/cirrhosis/jaundice	54/12/14/1	14/2/5/0	*.082*	5/2/4/0	4/0/1/0	5/0/0/0	*.280*
Liver disease							
HCC/ICC/liver metastasis/BC/Others	30/1/38/7/5	9/0/11/0/1	*.078*	7/0/4/0/0	2/0/2/0/1	0/0/5/0/0	*.004*
Preoperative liver function							
ICGR15 (%)	14.6±9.3	13.9±7.5	*.803*	14.1±8.3	14.2±9.9	13.3±3.1	
Hepatectomy							
Limited resection/ Lateral segmentectomy	38/5	15/6	*.327*	7/4	4/1	4/1	*.269*
Surgical records							
Blood loss (ml)	1040±984	279±430	*.0054*	470±512	35±27	59±48	

Red cell transfusion rate (No/Yes)	54/27	36/12	*.032*	9/2	5/0	5/0	*.408*
Total operation time (minutes)	418±144	300±173	*.169*	387±178	163±78*	231±106	
Transection time (minutes)	56±20	27±21	*.055*	43±37	16±2**	51±38	
Outcome							
Hospital death (No/Yes)	80/1	21/0	*.580*	11/0	5/0	5/0	*1.0*
Hepatectomy-related complications (No/Yes)	73/8	21/0	*.552*	11/0	5/0	5/0	*1.0*
Uncontrolled ascites* (No/Yes)	74/7	21/0	*.039*	11/0	5/0	5/0	*1.0*
Bile leakage (No/Yes)	71/10	21/0	*.911*	11/0	5/0	5/0	*1.0*
Intraabdominal abscess formation (No/Yes)	73/8	21/0	*.638*	11/0	5/0	5/0	*1.0*
Hospital stay (days)	24±12	13±7	*.0096*	17±11	9±3	7±1	

For abbreviations, see Table 2

*; $p<0.05$ *vs.* the *LigaSure V group*. **; $p<0.01$ *vs.* the *Harmonic UC group*.