Surg Today (2016) 46:535–542
DOI 10.1007/s00595-015-1189-0

ORIGINAL ARTICLE

Comparisons of financial and short-term outcomes between laparoscopic and open hepatectomy: benefits for patients and hospitals

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Received: 19 February 2015 / Accepted: 11 May 2015 / Published online: 30 May 2015

Abstract
Purposes This retrospective analysis compared the cost outcomes for both patients and hospitals, as well as the short-term outcomes, for laparoscopic hepatectomy (LH) and open hepatectomy (OH).
Methods The subjects comprised 70 patients who underwent LH or OH. The total hospital charge was calculated using the Japanese lump-sum payment system according to the diagnosis procedure combination.
Results Of the 70 patients, 10 in the LH group and 16 in the OH group underwent primary single limited/anatomic resection or left lateral sectoriectomy. The operation time, blood loss, and postoperative complications did not differ significantly between the two groups. The median [range] time of inflow occlusion was significantly longer [120 (50–194) vs. 57 (17–151) min, $P = 0.03$] and the postoperative hospital stay was significantly shorter [5 (4–6) vs. 9 (5–12) days, $P < 0.01$] in the LH group than in the OH group, respectively. The mean ± standard deviation surgical costs (1307 ± 596 vs. 1054 ± 365 US$, $P = 0.43$) and total hospital charges (12046 ± 1174 vs. 11858 ± 2096 US$, $P > 0.99$) were similar in the LH and OH groups, respectively, although the charges per day were significantly higher in the LH group than in the OH group (1388 ± 217 vs. 1016 ± 134 US$, $P < 0.01$).
Conclusions The costs to patients for LH are similar to those for OH. However, LH provides a financial advantage to hospitals due to a reduced hospital stay and comparable surgical costs.

Keywords Laparoscopic hepatectomy · Financial benefit · Hospital cost · Patient satisfaction · Open hepatectomy

Abbreviations

LH	Laparoscopic hepatectomy
OH	Open hepatectomy
POD	Postoperative day
SD	Standard deviations

Introduction

Laparoscopic hepatectomy (LH) is increasingly used worldwide [1–6]. LH is associated with a decreased blood loss, reduced postoperative morbidity, and shorter length of hospital stay, with no significant difference in the oncological outcomes, compared with open hepatectomy (OH) [7]. Despite these advantages of LH, few reports have addressed its financial aspects in the United States and Europe. The overall hospital costs of LH have been found to be equivalent to those of OH in the United States [8], and other studies have found that LH is more cost-effective than OH in the United States [10] and the United Kingdom [9]. To the best of our knowledge, no reports have focused on the financial aspects of LH in Asia, including Japan, although

Electronic supplementary material The online version of this article (doi:10.1007/s00595-015-1189-0) contains supplementary material, which is available to authorized users.

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LH is also gaining popularity there [11, 12]. In principle, healthcare providers should select the most effective treatment for their patients regardless of cost. A questionnaire-based survey of 559 patients in a Japanese hospital found that 88 % of these patients were interested in their hospital charges [13]. Moreover, patients in the United States of lower socioeconomic status were found to be more likely to avoid expensive treatment, regardless of the survival or toxicity [14].

LH may be used more frequently if it shows financial benefits in clinical practice in addition to its short-term advantages [7]. This retrospective analysis investigated the financial outcomes for patients and hospitals and the short-term clinical outcomes of LH and OH.

Methods

Patients

Between April 2002 and October 2013, 380 patients underwent liver resections at Asahi General Hospital, a municipal hospital covering approximately 400,000 people. The first author (Y. K.) started to work at the hospital on April 2012 as a senior staff member of hepato-biliary-pancreatic surgery. Between April 2012 and October 2013, our surgical team, including the first author, performed 70 liver resections. LH has been performed at our center since December 2012 with technical assistance for the first four patients provided by two expert laparoscopic liver surgeons (H. K. and Y.O.). The clinical records of these patients were reviewed retrospectively from a prospectively maintained database. All operations were performed after obtaining informed consent from the patients.

Indications and surgical procedures for OH and LH

Liver tumors suspected of malignancy were indicated for liver resection. Major hepatectomy was defined as the resection of three or more contiguous liver segments [15]. Between April and November 2012, all liver resections were performed using an open approach; since December 2012, liver resections have been performed using laparoscopic or open approaches after careful selection of patients. Exclusion criteria for LH included: lesions close to or invading the root of the hepatic veins or the inferior vena cava, a history of previous hepatectomy or any previous surgery potentially causing severe adhesion around the liver, and concomitant cardiopulmonary diseases. A pure laparoscopic approach was not used for hemi-hepatectomy until the team became more experienced. Before surgical resection, patients were routinely evaluated using chest and abdominal contrast-enhanced computed tomography, magnetic resonance imaging with Gd-EOB-DTPA (Bayer Schering Pharma, Germany), and ultrasonography. Positron emission tomography was performed when necessary. The operative procedures for resection of hepatocellular carcinoma were selected according to Makuuchi's criteria [16], whereas non-anatomic limited resection was used for liver metastases, retaining as much parenchymal liver volume as possible in case of future repeated hepatectomy [17]. Both LH and OH were performed on patients under a combination of general and epidural anesthesia. For OH, an inverted L-shaped incision was made for tumors in the right liver and a median incision for tumors in the left liver. For LH, the patient was placed in the supine position for resection of tumors in the left liver and in the left lateral decubitus position with the right arm suspended for resection of tumors in the right liver. A 12 mm trocar was placed in the umbilicus and the intra-abdominal pressure was maintained at 10–12 mmHg. Two 12 mm trocars and two 5 mm trocars were added in the appropriate triangular positions, depending on the location of the tumor and the resection procedure used. In addition, a balloon-tipped trocar (Olympus Co, Tokyo, Japan) was placed in the ninth intercostal space, when necessary. A 45° or 30° laparoscope was routinely used.

Parenchymal transection for OH was performed using the clamp crushing method with curved shears (Harmonic Focus; Ethicon Endo Surgery Industries, Cincinnati, OH, USA) or a bipolar vessel sealing (BiClamp; ERBE, Tübingen, Germany). By contrast, the clamp crushing method and/or an ultrasonic dissector (SonoSurg; Olympus Co) was utilized for parenchymal transection during LH with both ultrasonic laparoscopic coagulation shears (SonoSurg; Olympus Co) and laparoscopic bipolar vessel sealing (BiClamp for LAP forceps; ERBE). The inflow occlusion technique (the Pringle maneuver [18]) was performed for both OH and LH in principle, and was applied in an intermittent manner, with 15 min of occlusion alternated with 5 min of reperfusion. Intraparenchymal vessels were divided using a ligature for OH and endoscopic clips (Hem-o-Lok clip; Weck Closure Systems, Research Triangle Park, NC, USA) for LH. Unfragmented specimens resected by LH were placed in a plastic bag and retrieved through a small incision (normally an extension of the umbilical incision). A drainage tube was placed over the resected surface.

Postoperative management

All patients were transferred to the surgical ward after the operation. Blood tests (complete blood count, biochemical measurements, and coagulation profiles) and chest/abdominal radiographs were routinely performed on postoperative days (PODs) 1, 3, and 5. The concentration of total bilirubin in the discharge from the drainage tube was also analyzed on PODs 1, 3, and 5. Narcotic analgesics and/or nonsteroidal anti-inflammatory drugs were administered intravenously or orally to relieve postoperative pain when necessary. The epidural catheter was removed on POD 4, and the drainage tube was removed after POD 3 when the total volume of the discharge was under 200 mL/day and the concentration of total bilirubin in the discharge was under 2.0 mg/dL. Bile leakage was defined as a total bilirubin concentration in the discharge greater than 3.0 mg/dL. The patients were discharged from the hospital when an improved liver function was confirmed (e.g., aspartate aminotransferase <100 U/L, total bilirubin <1.5 mg/dL, and international normalized ratio of prothrombin time <1.5 in the blood), when there was no drainage tube and no further need for intravenous analgesics, and when they had recovered from impaired activities of daily living.

Surgical costs in the operating room and total costs of treatment

Surgical costs in the operating room included charges for anesthesia, all disposable instruments, and medical agents. The costs of BiClamp, BiClamp for LAP, and SonoSurg were excluded because they were reusable instruments. Hospital charges were calculated using the Japanese lump-sum payment system according to the Diagnosis Procedure Combination (the Japanese version of the Diagnostic Related Groups/Prospective Payment System in the US) [19]. Briefly, the payment system comprised a Diagnosis Procedure Combination component, which includes the hospital basic fee and charges for medications, and a fee-for-service component, which includes charges for surgical procedures and anesthesia. The amount of payment per day in the Diagnostic Procedure combination component decreases gradually on three levels [19]. In general, 70–90 % of the hospital charge is covered by the Japanese national health insurance, with the percentage mainly depending on patient age. The Japanese national health insurance presently covers only two procedures for LH: laparoscopic limited resection and laparoscopic left lateral sectoriectomy, whereas it covers minutely classified procedures for OH (Supplementary Table 1).

Statistical analysis

Continuous variables related to costs are expressed as the means ± standard deviations (SD) and compared between groups using Student's t test. Other continuous values are expressed as the median [range] and compared using Wilcoxon's rank-sum test. Categorical variables are expressed as number (%) and compared using Fisher's exact test or the Chi square test, as appropriate. A P value less than 0.05 was considered to be statistically significant. All statistical analyses were conducted using the JMP software program (version 9.0.2; SAS Institute Inc., Cary, NC).

Results

The flowchart of the included patients is shown in Fig. 1. Of the 70 patients, 65 underwent liver resection by a single surgeon (Y.K.), including 17 (26 %) who underwent LH and 48 (74 %) who underwent OH. These numbers corresponded to the initial experiences of LH and OH in our surgical team, including that of the first author. After the introduction of LH to our center in December 2012, 39 % (17/44) of hepatectomies were performed using the laparoscopic approach. To compare the financial and short-term outcomes, patients who underwent additional synchronous procedures except for cholecystectomy were excluded. Additionally, only patients who underwent primary single limited/anatomic resection or left lateral sectoriectomy were selected, both to match the magnitude of resection as well as to apply the Japanese payment system (Supplementary Table 1). Thus, 16 patients who underwent OH, eight from April to November 2012 and eight from December 2012 to October 2013, and 10 who underwent LH, all from December 2012 to October 2013, were compared. The demographic data of these patients are shown in Table 1. There was no significant difference between the LH and OH groups regarding the median [range] age [68 (44–79) vs. 72 (38–81)] years, $P = 0.46$), male to female ratio (6:4 vs. 8:8, $P = 0.70$), or American Society of Anesthesiologists physical status score [2 (2–3) vs. 2 (1–3), $P = 0.58$]. The prevalence rates of chronic hepatitis [60 % (6/10) vs. 56 % (9/16), $P = 0.85$] and previous surgery [30 % (3/10) vs. 50 % (8/16), $P = 0.43$] were also similar between the LH and OH groups, respectively.

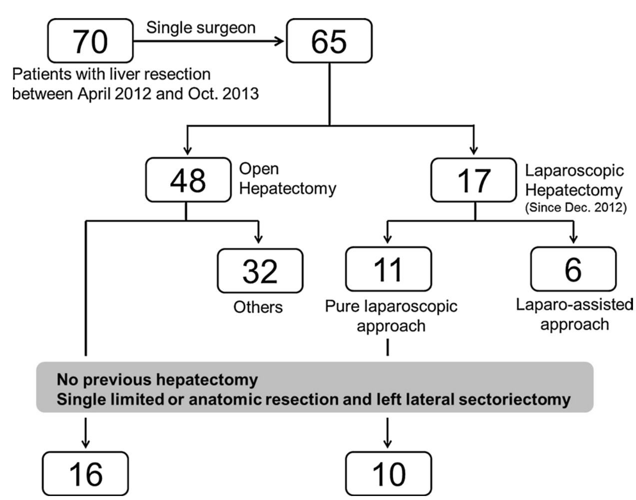

Fig. 1 Flowchart of the included participants

Table 1 Demographic and clinical characteristics of the LH and OH groups

Variables	LH group ($n = 10$, 15 %)	OH group ($n = 16$, 25 %)	*P* value
Age, year*	68 [47–79]	72 [38–81]	0.46
Male:female ratio	6:4	8:8	0.70
BMI*	27 [18–32]	24 [18–31]	0.16
Child-pugh score, pts*	5 [5, 6]	6 [5–9]	0.07
Chronic hepatitis, *n* (%)	6 (60)	9 (56)	0.85
Tumor location			
I/II/III/IV	0/1/1/0	0/2/0/2	0.65
V/VI/VII/VIII	4/1/1/2	5/1/4/1	0.41
Preoperative blood data*			
Albumin level, g/dL	4.1 [3.8–4.7]	4 [3.3–4.6]	0.58
Serum creatinine, mg/dL	0.79 [0.59–1.14]	0.81 [0.55–3.74]	0.50
Total bilirubin, mg/dL	0.6 [0.3–1.1]	0.7 [0.5–1.2]	0.22
PT-INR	1.06 [0.95–1.23]	1.11 [0.97–1.31]	0.34
Platelet count, $\times 10^4/\mu L$	17.3 [10.7–30.3]	16.3 [7.3–27.4]	>0.99
Performance status	0	0	0.58
ASA physical status score*	2 [2, 3]	2 [1–3]	
Previous surgery, *n* (%)	3 (30)†	8 (50)‡	0.43

ASA American Society of Anesthesiologists, *BMI* body mass index (calculated as weight in kilograms divided by height in meters squared), *PT-INR*, international normalized ratio of prothrombin time

* Median [range]

† Left hemicolectomy ($n = 1$), laparoscopic-assisted partial gastrectomy ($n = 1$), and high anterior resection ($n = 1$)

‡ Choledochotomy ($n = 1$), open cholecystectomy ($n = 1$), laparoscopic cholecystectomy ($n = 1$), appendectomy ($n = 2$), distal gastrectomy ($n = 1$), pancreaticoduodenectomy ($n = 1$), right colectomy ($n = 1$)

Table 2 Surgical outcomes in the LH and OH groups

Variables	LH group ($n = 10$, 15 %)	OH group ($n = 16$, 25 %)	*P* value
Surgical procedure, *n* (%)			
Limited resection	6 (60)	10 (63)	>0.99
Anatomic resection of single segment	3 (30)	5 (31)	>0.99
Left lateral sectoriectomy	1 (10)	1 (6)	>0.99
Operative factors			
Operative time*, min	369 [165–602]	258 [123–490]	0.11
Operative blood loss*, L	150 [0–675]	541 [0–1716]	0.07
Inflow occlusion, *n* (%)	6 (60)	14 (88)	0.16
Time of inflow occlusion*, min	120 [50–194]	57 [17–151]	0.03
Transfusion*			
Red blood cell concentrate, mL	0	0 [0–280]†	0.43
Fresh frozen plasma, mL	0	0 [0–360]‡	0.43
Platelet concentrate, mL	0	0	>0.99

AST aspartate aminotransferase, *T-Bil* serum total bilirubin, *PT-INR* international normalized ratio of prothrombin time, *POD* postoperative day

* Median [range]

†‡ Red blood cell concentrate and fresh frozen plasma were transfused for one identical patient in the OH group but not for the other 15 patients

The surgical outcomes are shown in Table 2. Six patients (60 %) in the LH group and 10 (63 %) in the OH group underwent limited non-anatomic resection, three (30 %) and five (31 %), respectively, underwent anatomic resection of a single segment, and one (10 %) and one (6 %), respectively, underwent left lateral sectoriectomy

Table 3 Postoperative outcomes in the LH and OH groups

Variables	LH group ($n = 10$, 15 %)	OH group ($n = 16$, 25 %)	P value
Histological factors			
Tumor size, cm	3.6 [0.8–5.5]	3.0 [0.8–6.0]	0.98
Positive surgical margin, *n* (%)	0	0	
Hepatocellular carcinoma, *n* (%)	4 (40)	9 (56)	0.69
Metastasis, *n* (%)	3 (30)	2 (13)	0.34
Others, *n* (%)	3 (30)	5 (31)	>0.99
Postoperative factors			
AST (U/L)*			
POD 1	310 [147–1424]	186 [68–386]	0.01
POD 3	115 [50–413]	65 [29–169]	0.18
T-Bil (mg/dl)*			
POD 1	0.9 [0.5–1.6]	1 [0.5–1.7]	0.79
POD 3	0.9 [0.5–1.5]	0.8 [0.4–1.2]	0.10
PT-INR*			
POD 1	1.14 [1.01–1.46]	1.19 [1.04–1.49]	0.62
POD 3	1.13 [1.00–1.80]	1.16 [1.01–1.29]	0.67
Discharge of drainage tube (mL)*			
POD 1	30 [10–90]	150 [2–400]	<0.01
POD 3	10 [0–190]	85 [0–300]	0.04
Morbidity Clavien–Dindo‡			
Grade I or II, *n* (%)	1 (10)§	2 (8)†	>0.99
Grade III or IV, *n* (%)	0	0	
Mortality	0	0	
Use of intravenous narcotics			
None	7 (70)	5 (31)	0.11
Frequency (times)	0 [0–2]‖	1 [0–7]	0.04
Postoperative hospital stay, day*	5 [4–6]	9 [5–12]	<0.01
Total hospital stay, day*	8 [7–13]	12 [9–15]	<0.01

AST aspartate aminotransferase, *T-Bil* serum total bilirubin, *PT-INR* international normalized ratio of prothrombin time, *POD* postoperative day

* Median [range]

‡ Clavien PA, Barkun J, de Oliveira ML, et al. Ann Surg. 2009; 250:187–196

§ Bile leakage ($n = 1$)

† Cholangitis ($n = 1$), abscess ($n = 1$)

‖ One patient required two treatments of intravenous narcotics and two patients required one treatment each

($P > 0.99$). The median [range] operative times were 369 (165–602) min in the LH group and 258 (123–490) min in the OH group ($P = 0.11$), and the median blood loss was 150 (0–675) and 541 (0–1716) mL, respectively ($P = 0.07$). One patient (6 %) in the OH group received a transfusion, including both red blood cell concentrate (280 mL) and fresh frozen plasma (360 mL). The median [range] time of inflow occlusion was significantly longer in the LH group than in the OH group [120 (50–194) vs. 57 (17–151) min, $P = 0.03$], with inflow occlusion performed in 6 (60 %) and 14 (88 %) patients, respectively ($P = 0.16$). The postoperative outcomes are detailed in Table 3. The median [range] aspartate aminotransferase concentration on POD 1 was significantly higher [310 (147–1424) vs. 186 (68–386) U/L, $P = 0.01$] and the median [range] volumes of discharge from the drainage tube on PODs 1 [30 (10–90) vs. 150 (2–400) mL, $P < 0.01$] and 3 [10 (0–190) vs. 85 (0–300) mL, $P = 0.04$] were significantly lower in the LH group than in the OH group. The overall morbidity rates were similar between the two groups [1 (10 %) vs. 2 (8 %), $P > 0.99$], with one patient in the LH group experiencing bile leakage and one patient each in the OH group experiencing cholangitis and an abscess. No patient in either group experienced a Grade III/IV morbidity [20] or mortality. Seven patients (70 %) in the LH group did not require intravenous narcotics postoperatively compared to 5 patients (31 %) in the OH group ($P = 0.11$). The frequency of intravenous narcotics used per patient was significantly lower in the LH group than in the OH group [0 (0–1) vs. 1 (0–7) time, $P = 0.04$]. The median [range] postoperative hospital stay was significantly shorter in the LH group than in the OH group [5 (4–6) days vs. 9 (5–12) days, $P < 0.01$].

The surgical costs and total hospital charges are shown in Table 4. The mean ± SD operation charge was significantly higher in the LH group than in the OH group (5303 ± 768 US$ vs. 3963 ± 510 US$, $P < 0.01$). The mean ± SD surgical costs (1307 ± 596 US$ vs. 1054 ± 365 US$, $P = 0.43$) and total hospital charges (12046 ± 1174 US$ vs. 11858 ± 2096 US$, $P > 0.99$) were similar between the LH and OH groups. The mean ± SD patient charge per day was significantly higher in the LH group than in the OH group (1388 ± 217 US$ vs. 1016 ± 134 US$, $P < 0.01$). The rough balance, defined as the total charge for treatment minus surgical costs, was similar between these two groups (10739 ± 1109 US$ vs. 10804 ± 1952 US$, respectively, $P = 0.87$). The rough balance per day was significantly higher in the LH group than in the OH group (1234 ± 170 US$ vs. 926 ± 133 US$, $P < 0.01$).

Table 4 Financial outcomes in the LH and OH groups

Variables	LH group ($n = 10$, 15 %)	OH group ($n = 16$, 25 %)	P value
Operation charge*			
Yen	5,30,280 ± 76780	3,96,256 ± 51022	<0.01
US$‡	5303 ± 768	3963 ± 510	
Surgical costs*,§			
Yen	1,30,686 ± 59613	1,05,440 ± 36529	0.43
US$‡	1307 ± 596	1054 ± 365	
Total charge for the treatment*			
Yen	12,04,614 ± 117364	11,85,839 ± 209570	>0.99
US$‡	12046 ± 1174	11858 ± 2096	
Charge per day*			
Yen	1,38,805 ± 21669	1,01,551 ± 13439	<0.01
US$‡	1388 ± 217	1016 ± 134	
Rough balance*,†			
Yen	10,73,928 ± 110879	10,80,399 ± 195243	0.87
US$‡	10739 ± 1109	10,804 ± 1952	
Rough balance per day*			
Yen	1,23,373 ± 17032	92,639 ± 13336	<0.01
US$‡	1234 ± 170	926 ± 133	

* Mean ± SD

‡ Calculated on an exchange rate of 100 yen to the dollar (November 2013)

§ Including charges for anesthesia, disposable instruments, and medical agents

† (Total charge for the treatment) − (surgical costs)

Discussion

The results herein presented demonstrate that the surgical costs and total charges for LH were comparable to those of OH, whereas LH reduces the discharge from the drainage tube and the length of hospital stay. These findings indicate that hospital charges to patients are similar for LH and OH, while hospitals can gain a financial advantage per day by performing LH rather than OH. These financial outcomes were mainly due to the shorter hospital stay for LH compared with OH. In addition, the equivalent surgical costs between LH and OH also influenced the outcomes. The surgical costs for LH are supposed to be higher than those for OH because LH tends to require more surgical devices compared to OH. The patients should be informed preoperatively that the financial burden of LH is comparable to that of OH because the hospital charges, in addition to treatment quality, cannot be completely ignored in favor of patient satisfaction [14, 21].

The oncological outcomes are most important in selecting treatment for malignancy. To the best of our knowledge, no studies have shown poorer survival outcomes in patients undergoing LH compared with OH for hepatocellular carcinoma or colorectal liver metastasis [4, 22–24]. To achieve similar oncological outcomes to OH, factors such as the surgical procedures, surgical margin, and tumor detection methods during LH should be considered. Theoretical disadvantages of LH, such as the lack of tactile feedback and the inflexibility of intraoperative ultrasonography, may cause tumors to be exposed or unidentified [25], resulting in poorer oncological outcomes. In addition, anatomic segmentectomy, which has demonstrated oncological advantages in patients with hepatocellular carcinoma [26, 27], is technically demanding when performed laparoscopically [28]. To theoretically optimize the oncological outcomes, surgical margins were confirmed to be negative and all patients with hepatocellular carcinoma underwent laparoscopic anatomic resection.

The short-term outcomes of patients in our LH group were similar to those reported previously, suggesting that LH is safe while reducing the length of hospital stay [7, 8, 22, 24]. Shorter hospital stays were due in part to decreased discharge through the drainage tube and were also attributable to better postoperative pain control in patients undergoing LH, although intravenous narcotics were not systematically administered in the present study. LH was reportedly associated with a shorter duration and lower total amount of intravenous narcotic requirements [4, 29]. The increased aspartate aminotransferase concentration in our LH group was most likely caused by the longer time of inflow occlusion, with assays of individual patients showing that this longer time was due to our surgical team being unfamiliar and less experienced with the techniques rather than to LH itself. The learning curve for minor hepatectomy was found to be overcome after 60 operations [30]. The rate of postoperative complications, which has been reported to be lower in patients undergoing LH than OH [7, 8], was similar in our two groups, due in part to the small number of patients undergoing LH. However, LH was safely introduced and performed with minimal complications, with only one patient developing postoperative bile leakage without the need for any intervention.

There are several limitations associated with this study, including its retrospective nature, the limited number of patients, and the lack of an evaluation of reusable instruments and the labor costs. Another limitation of this study is that it compared the financial outcomes of patients undergoing minor hepatectomy (limited/anatomic resection and left lateral sectoriectomy), which is covered by the Japanese national health insurance for both LH and OH, but it did not evaluate the costs in patients undergoing major hepatectomy. The financial benefits for patients and hospitals are dependent on the health care system, which can change according to the time and countries. Therefore, a significant increase in the number of reports on cost comparisons between LH and OH in different countries is essential to lead to a consensus concerning the financial benefits of LH.

In conclusion, the costs of LH to patients are similar to that of OH, whereas LH provides hospitals with financial advantages. The latter outcome is due to a combination of a reduced hospital stay and comparable surgical costs of LH. This finding may improve patient satisfaction in clinical practice, thus supporting LH from the financial point of view.

Author contributions

Study conception and design: Kawaguchi, Tanaka. Acquisition of data: Kawaguchi, Yamamoto, Otani, Ohashi, Sugawara, Koike, Ishida. Analysis and interpretation of data: Kawaguchi, Nagai, Nomura, Otsuka. Manuscript drafted by: Kawaguchi. Critical revision: Kaneko, Kokudo, Tanaka.

Acknowledgments The authors thank Ms. Junko Ibato, Mr. Hidetoshi Shimada, Mr. Takayuki Ota, Mr. Nozomu Senbonmatsu, Mr. Yui Shinno, Mr. Keizo Katagiri, Dr. Kyoji Ito, Dr. Keishi Kawasaki, and Dr. Yosuke Suka for the acquisition of the financial data and helpful insights.

Conflicts of interest The authors declare that they have no conflicts of interest.

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