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Perioperative Outcomes of Laparoscopic Minor Hepatectomy for Hepatocellular Carcinoma in the Elderly

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Abstract

Introduction This study aims to evaluate the safety and feasibility of laparoscopic minor hepatectomy (LMH) in elderly patients with hepatocellular carcinoma (HCC).

Methods A total of 40 consecutive elderly (≥ 70 years) patients were compared with 94 young patients (< 70 years). The 40 patients were also compared with 85 consecutive elderly patients who underwent open minor hepatectomies (OMH). After 1:1 propensity-score matching (PSM), 32 LMHs were compared with 32 OMHs in elderly patients.

Results Comparison between the baseline characteristics of elderly and young HCC patients showed that elderly patients were significantly more likely to have comorbidities, ASA score > 2, non-hepatitis B, previous liver resection and larger tumor size. Comparison between perioperative outcomes demonstrated that elderly patients were significantly more likely to have a longer operation time, increased blood loss, increased need for blood transfusion, longer Pringles duration and longer postoperative stay. Comparison between LMH and OMH in elderly patients demonstrated no significant difference in baseline characteristics except the LMH cohort were significantly more likely to have > 1 comorbidity, higher platelet count and lower median AFP level. Comparison between outcomes before and after PSM demonstrated that LMH was associated with longer operation time, increased blood loss, longer Pringles duration but decreased postoperative pulmonary complications and shorter postoperative stay compared to OMH.

Conclusion LMH is safe and feasible in elderly patients with HCC. However, LMH in elderly patients is associated with poorer perioperative outcomes compared to LMH in young patients. Comparison between LMH and OMH in elderly patients demonstrated advantages in terms of decreased pulmonary complications and shorter length of stay at the expense of increased operation time and blood loss.

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Introduction

An aging population is a major issue worldwide especially in developed countries [1, 2]. Singapore has the third longest life expectancy in the world with an average life expectancy of 83 years according to the 2017 World Health Organization report [3]. Hepatocellular carcinoma (HCC) is a common malignancy in the region due to the prevalence of hepatitis B, and it is not surprising that an increasing incidence of HCC is observed in elderly patients.

Elderly patients frequently present with more comorbidities especially cardiovascular and pulmonary disease which places them at an increased risk of postoperative complications than for young patients [2, 4]. This coupled with the increased risk of bleeding and liver decompensation after liver resection especially for HCC patients with cirrhosis [5] leaves many surgeons more reluctant to propose liver surgery for these specific groups of patients. Nonetheless, advances in surgical techniques and perioperative care have greatly improved the outcomes of hepatic surgery, allowing increasing numbers of patients even in those with comorbidities to undergo safe hepatectomy [5, 6]. Today, open hepatectomy is a well-accepted treatment modality for HCC even in elderly patients due to the reported safety and its excellent oncological outcomes [4–7].

In recent times, there has been a vast amount of interest in laparoscopic hepatectomy (LH) [8] and numerous studies have demonstrated that LH results in superior perioperative outcomes without compromising oncological outcomes in patients with malignancies including HCC [9–11]. This is despite HCC being frequently associated with liver cirrhosis which increases the risk of bleeding and technical difficulty of liver resection [9–11]. The role and benefits of LH in elderly patients remain less clear today although several recent studies [1, 2, 12, 13] have reported that the safety and advantages of LH can be translated to elderly patients. However, none of these studies have focused specifically on elderly patients with HCC, and most of these were small series with an even smaller number of HCC patients [1, 2, 12, 13]. The aim of this study was to evaluate the feasibility, safety and outcome of laparoscopic minor hepatectomy (LMH) in elderly patients with HCC. To our knowledge, this is the first study to date to focus specifically on the issue of LMH in elderly patients with HCC.

Methods

Between 2007 and 2016, 278 consecutive patients who underwent LH at Singapore General Hospital were retrospectively reviewed from a prospective database. The study was approved by our institution review board. Of these, 134 consecutive patients who underwent LMH for HCC were identified. A total of 40 consecutive elderly ($\geq$ 70 years) patients who underwent LMH were the focus of this study. This patient cohort was compared with 94 young patients (< 70 years) who underwent LMH for HCC during the same period.

From 2005 to 2015, 105 consecutive elderly patients underwent conventional open hepatectomy for HCC at our institution. Of these, patients who underwent major hepatectomy had tumors larger than 90 mm, who underwent concomitant radiofrequency ablation had more than 2 nodules or who had locally advanced HCC requiring adjacent organ resection were excluded. Finally, 85 consecutive elderly patients who underwent OMH were selected as the open control group.

The patients' clinical, radiological and pathological data were retrospectively reviewed and collected. Surgical data were collected from a prospective computerized database (OTM 10, IBM, Armonk, New York), whereas clinical data were collected from another prospective computerized clinical database (Sunrise Clinical Manager version 5.8, Eclipsys Corporation, Atlanta, Georgia).

Postoperative complications were classified according to the Clavien–Dindo grading system [14] and recorded up to 30 days or during the same hospitalization of surgery. Ninety-day mortality was defined as any death within 90 days from surgery. There was no specific protocol for the preoperative evaluation of elderly patients compared to young patients. Laboratory tests such as complete blood count, electrolyte panel, liver function tests and coagulation profile were routinely performed. Electrocardiogram, chest X-ray and preoperative evaluation by an anesthetist were also routinely performed. Specific tests such as echocardiography, myocardial perfusion scan or pulmonary function tests were only performed in individual cases if deemed necessary but in general were performed more liberally in elderly than in younger patients.

Definitions

The definitions used in this study were reported in our previous studies [15–17]. In this study, LMH was defined according to the traditional Brisbane 2000 classification [18] which included only resections 0 < 3 contiguous segments. Laparoscopic resection included all patients who underwent an attempted pure laparoscopic, robotic-assisted, hand-assisted laparoscopy or laparoscopic-assisted resections. Tumors involving segments 2, 3, 4b, 5 and 6 were defined as located in the anterolateral segments, whereas tumors involving segments 1, 7, 8 and 4a were defined as located in the difficult posterosuperior segments. An open conversion was defined as when a resection was attempted via the laparoscopic or hand-assisted approach but required an open incision to complete the resection. Conversion from pure laparoscopy to hand-assist was not considered an open conversion. Our operative technique has been previously described [15–17]. In general, this was not standardized and our technique including the type of laparoscopic instruments used evolved over time. This also varied according to individual surgeon preference and type of resection.

Statistical analyses were performed using the computer program Statistical Package for Social Sciences for

Table 1 Comparison between the baseline demographic and perioperative data of elderly (≥ 70) and young patients who underwent LMH for HCC

	All (n = 134)	Elderly (n = 40)	Young (n = 94)	p value
Gender, male (%)	97 (72.4)	26 (65.0)	71 (75.5)	0.212
Median age (range) (yrs)	62.5 (30–88)	74 (70–88)	58 (30–69)	**<0.001**
Comorbidity, n (%)				
Cardiac	14 (10.4)	10 (25)	4 (4.3)	**0.001**
Cerebrovascular accident	2 (1.5)	0	0 (2.1)	0.353
Renal	10 (7.5)	4 (10)	6 (6.4)	0.466
Diabetes	53 (39.6)	22 (55)	31 (33)	**0.017**
Pulmonary	10 (7.5)	6 (15)	4 (4.3)	0.065
Hypertension	74 (55.2)	33 (82.5)	41 (43.6)	**<0.001**
Hyperlipidemia	48 (35.8)	20 (50)	28 (29.8)	**0.026**
>1 comorbidity, n (%)	68 (50.7)	31 (77.5)	37 (39.4)	**<0.001**
Hepatitis B, n (%)	81 (60.4)	18 (45.0)	63 (67.0)	**0.017**
Previous abdominal surgery, n (%)	21 (15.7)	10 (25.0)	11 (11.7)	0.053
Previous liver resection, n (%)	8 (6.0)	5 (12.5)	3 (3.2)	**0.037**
ASA score, n (%)				0.062
1	17 (12.7)	4 (10)	13 (13.8)	
2	98 (73.1)	26 (65)	72 (76.6)	
3	19 (14.2)	10 (25)	9 (9.6)	
ASA > 2, n (%)	19 (4.2%)	10 (25)	9 (9.6)	**0.019**
Median AFP (range),	5.8 (1–27,864)	4.3 (1–26,758)	7.1 (1–27,864)	0.192
Median platelet count (range),	195 (59–483)	206 (59–466)	188 (64–483)	0.107
Median creatinine level (range),	84 (37–296)	88.5 (37–296)	82.5 (48–244)	**0.008**
Median tumor size mm (range)	27 (6–95)	30 (14–88)	25 (6–95)	**0.008**
Multifocal HCC, n (%)	23 (17.2)	6 (15)	17 (18.1)	0.665
Type of LMH, n (%)				0.348
Totally laparoscopic	124 (92.5)	37 (92.5)	87 (92.6)	
Hand-assisted laparoscopic	4 (3.0)	0	4 (4.3)	
Laparoscopic-assisted (hybrid)	6 (4.5)	3 (7.5)	3 (7.5)	
No of segments resected, n (%)				0.407
≤1	71 (53)	19 (47.5)	52 (55.3)	
>1	63 (47)	21 (52.5)	42 (44.7)	
Tumor involving difficult posterior-superior segments, n (%)	43 (32.1)	16 (40)	27 (28.7)	0.201
Liver cirrhosis on histology, n (%)	62 (46.3)	15 (37.5)	47 (50)	0.184

Bold values indicate statistically significant $p < 0.05$

Windows, version 21.0 (SPSS Inc, Chicago, IL, USA) and Stata (version 13, StataCorp). Univariate analyses were performed using Mann–Whitney U test, Chi-squared or Fisher's exact tests as appropriate. All tests were two-sided, and $p < 0.05$ was considered statistically significant. Sensitivity analyses by way of propensity-score matching were conducted. The laparoscopic and open patients were paired 1:1 using a greedy algorithm without replacement and with a caliper of 0.2, and adequacy of matching was assessed using kernel density and histogram plots. After propensity-score matching, both groups were well balanced for all variables. The Wilcoxon signed-rank test and exact McNemar's test (or the Cochran Q test when there are more than two levels) were, respectively, utilized to compare distributions and proportions, taking into account stratification by matched pairs.

Results

During the study period, 134 underwent LMH for HCC. Of these, 40 were elderly and 94 were young patients. The baseline characteristics and outcomes of these 134 patients are summarized in Tables 1 and 2.

Table 2 Comparison between the perioperative and oncologic outcomes of elderly and young patients who underwent LMH for HCC

	All LMH (n = 134)	Elderly (n = 40)	Young (n = 94)	p value
Median operating time (range) (min)	215 (50–595)	265 (80–530)	197.5 (50–595)	**0.002**
Median blood loss (range) (mL)	300 (0–5000)	500 (10–5000)	300 (0–5000)	**0.010**
Perioperative blood transfusion, n (%)	33 (24.6)	15 (37.5)	18 (19.1)	**0.024**
Median blood transfusion (range) (mL)	0 (0–3600)	0 (0–3600)	0 (0–2750)	**0.012**
Pringle maneuver applied, n (%)	43 (32.1)	16 (40)	27 (28.7)	0.201
Median duration of Pringle maneuver when applied (range) (min)	45 (5–150)	62.5 (30–130)	32 (5–150)	**0.001**
Open conversion, n (%)	21 (15.7)	8 (20)	13 (13.8)	0.369
Median postoperative stay (range), d	4 (1–58)	5 (1–26)	4 (2–58)	**0.014**
Postoperative morbidity, n (%)	26 (19.4)	11 (27.5)	15 (16.0)	0.122
Postoperative major (> G II) morbidity, n (%)	8 (6)	3 (7.5)	5 (5.3)	0.695
Postoperative 90-day mortality, n (%)	2 (1.5)	0	2 (2.1)	1.000
Reoperation, n (%)	4 (3.0)	2 (5.0)	2 (2.1)	0.371
Readmission, n (%)	6 (4.5)	2 (5.0)	4 (4.3)	0.849
Close resection margins $\leq$ 1 mm, n (%)	7 (5.2)	4 (10)	3 (3.2)	0.196
Median closest resection margin, mm (range)	6 (0–60)	5 (0–60)	4 (0–26)	0.697
Microvascular invasion, n (%)	26 (19.4)	7 (17.5)	19 (20.2)	0.716
Tumor grade, n (%)	50 (40.0)	17 (47.2)	33 (37.1)	0.295

Bold values indicate statistically significant $p < 0.05$

Comparison between LMH for HCC in elderly and young patients (Tables 1 and 2)

Comparison between the baseline characteristics demonstrated that elderly patients were significantly more likely to have cardiac disease, diabetes, hypertension and hyperlipidemia than young patients. They were also significantly more likely to have 2 or more comorbidities, American Society of Anaesthesiologists (ASA) score $\geq$ 3, tumors of larger size and previous liver resection. Elderly patients were significantly less likely to have hepatitis B. Comparison between outcomes showed that elderly patients had significantly longer operation time, increased blood loss, increased need for blood transfusion, longer Pringles time (when applied) and longer postoperative stay.

Comparison between LMH and OMH for HCC in elderly patients before and after propensity-score matching (Tables 3 and 4)

Comparison between the baseline characteristics of LMH and OMH in elderly patients demonstrates no significant difference except an increased frequency in patients having more than 1 comorbidity, lower median AFP level and higher median platelet count in patients who underwent LMH. Comparison between LMH and OMH outcomes demonstrated a significantly longer operation time, increased blood loss, shorter hospital stay and decreased frequency of pulmonary complications with LMH. After 1:1 propensity-score matching, the baseline characteristics of both groups were well matched. Nonetheless, comparison between LMH and OMH in elderly patients demonstrated the same differences in outcomes. The type of pulmonary complications occurring in elderly patients after hepatectomy were pleural effusion (n = 7), pneumonia (n = 4), postoperative respiratory failure requiring intubation (n = 2) and pulmonary embolism (n = 1).

Discussion

Presently, with improvement in surgical techniques and advancements in laparoscopic equipment, LH is increasingly adopted in numerous institutions worldwide [15–17]. The role of LH in elderly patients remains debatable, and to date, most studies have been carried out to analyze outcomes in patients with liver metastases [2, 13, 20] or various malignancies [1, 12, 19–22]. To our knowledge, there have been no studies specifically evaluating the outcomes of LH in elderly patients with HCC to date. The first study of LH for elderly patients was published in 2013 [22] which reported no difference in outcomes between 25 ($\geq$ 70 years) elderly patients and 35 young patients who underwent LH for malignant liver tumors. Only 9 of the 25 elderly patients had HCC, and all were cirrhotic. Subsequently, Chan et al. [1] compared the outcomes of LH in 17 elderly patients with 34 elderly patients who underwent OH for malignant liver tumors in a matched case-

Table 3 Comparison between the baseline demographic and perioperative data of elderly (≥ 70 years) patients who underwent LMH versus OMH for HCC before and after 1:1 propensity-score matching

	All elderly (n = 125)	LMH (n = 40)	OMH (n = 85)	p value	1:1 matching		
					LMH (n = 32)	OMH (n = 32)	p value
Gender, male (%)	86 (68.8)	26 (65.0)	61 (70.6)	0.529	23 (71.9)	23 (71.9)	1.0000
Median age (range), yrs	74 (70–88)	74 (70–88)	74 (70–88)	0.712	73 (70–88)	74.5 (70–83)	0.3392
Comorbidity, n (%)							
Cardiac	28 (22.4)	10 (25.0)	18 (21.2)	0.632	7 (21.9)	11 (34.4)	0.4807
Cerebrovascular accident	2 (1.6)	0	2 (2.4)	0.328	0 (0.0)	0 (0.0)	1.0000
Renal	12 (9.6)	4 (10)	8 (9.4)	0.917	4 (12.5)	5 (15.6)	0.7389
Diabetes	58 (46.4)	22 (55.0)	36 (42.4)	0.186	19 (59.4)	16 (50.0)	0.6121
Pulmonary	13 (10.4)	6 (15.0)	7 (8.2)	0.248	6 (18.8)	4 (12.5)	0.5271
Hypertension	90 (72.0)	33 (82.5)	57 (67.1)	0.073	26 (81.3)	25 (78.1)	0.8886
Hyperlipidemia	56 (44.8)	20 (50)	36 (42.4)	0.423	15 (46.9)	17 (53.1)	0.7237
> 1 comorbidity, n (%)	81 (64.8)	31 (77.5)	50 (58.8)	**0.041**	25 (78.1)	25 (78.1)	1.0000
Hepatitis B, n (%)	47 (37.6)	18 (45.0)	29 (34.1)	0.136	14 (43.8)	13 (40.6)	0.8474
Previous abdominal surgery, n (%)	22 (17.6)	10 (25.0)	12 (14.1)	0.052	8 (25.0)	5 (15.6)	0.4054
Previous liver resection, n (%)	11 (8.8)	5 (12.5)	6 (7.1)	0.316	4 (12.5)	1 (3.1)	0.3750
ASA score, n (%)				0.528			1.0000
1	8 (6.4)	4 (10.0)	4 (4.7)		3 (9.4)	3 (9.4)	
2	85 (68.0)	26 (65.0)	59 (69.4)		20 (62.5)	21 (65.6)	
3	32 (25.6)	10 (25.0)	22 (25.9)		9 (28.1)	8 (25.0)	
ASA >2, n (%)	33 (26.4)	10 (25.0)	23 (27.1)	0.808	9 (28.1)	9 (28.1)	1.0000
Median AFP (range)	8.6 (1–29,483)	4.3 (1–26,758)	11.5 (1.2–29,483)	**0.018**	4.5 (1–26,758)	8.6 (1.6–16,731)	0.8370
Median platelet count (range)	180 (59–466)	206 (59–466)	175 (66–378)	**0.032**	190.5 (59–466)	192 (113–378)	0.9329
Median creatinine (range)	90 (37–646)	89 (37–296)	91 (45–646)	0.975	88.5 (37–296)	91.5 (51–646)	0.8737
Median tumor size, mm (range)	33 (5–95)	30 (14–88)	35 (5–95)	0.693	29.5 (14–80)	35 (5–90)	0.6136
Multifocal HCC, n (%)	20 (16.0)	6 (15)	14 (16.5)	0.834	4 (12.5)	7 (21.9)	0.3657
No of segments resected				0.235			0.3359
≤1	69 (55.2)	19 (47.5)	50 (58.8)		16 (50)	21 (65.6)	
>1	56 (44.8)	21 (52.5)	35 (41.2)		16 (50)	11 (34.4)	
Location in difficult posterior-superior segments, n (%)	48 (38.4)	16 (40)	32 (37.6)	0.801	12 (37.5)	9 (28.1)	0.5127
Liver cirrhosis on histology, n (%)	51 (40.8)	15 (37.5)	36 (42.4)	0.607	12 (37.5)	11 (34.4)	0.8348

Bold values indicate statistically significant $p < 0.05$

controlled study. They demonstrated decreased blood loss and hospital stay in the LH cohort. Only 12 of the 17 patients had HCC, and 9 were cirrhotic. More recently, investigators from France demonstrated first in a single-center study [2] and subsequently in a multi-institution series [20] that laparoscopic major hepatectomy can be performed safely in elderly patients with similar outcomes to young patients and with the same advantages of decreased length of stay and morbidity over the open approach. The indications for resection were colorectal metastases in the single-center study [2], and only 10 of the 35 elderly patients in the multi-institution series had HCC [20]. The advantages of LH for colorectal liver metastases in the elderly were recently confirmed in a recent large European multi-institution study [13].

The results of our present study demonstrate that contrary to earlier reports, compared to young patients, LMH for HCC in elderly patients was associated with significantly longer operation time, increased blood loss, increased need for blood transfusion, longer Pringles time (when applied) and longer postoperative stay. In our opinion, this observation was not unexpected as elderly

Table 4 Comparison between the perioperative and oncologic outcomes of elderly patients who underwent LMH versus elderly patients who underwent OMH before and after 1:1 propensity-score matching

	All elderly (n = 125)	LMH (n = 40)	OMH (n = 85)	p value	1:1 matching		
					LMH (n = 32)	OMH (n = 32)	p value
Median operating time (range), min	175 (60–530)	265 (80–530)	155 (60–485)	**<0.001**	270 (80–530)	167.5 (60–320)	**0.0002**
Median blood loss (range), mL	300 (10–5000)	500 (10–5000)	300 (10–2300)	**0.021**	500 (10–5000)	350 (10–1500)	**0.0460**
Perioperative blood transfusion, n (%)	36 (28.8)	15 (37.5)	21 (24.7)	0.141	12 (37.5)	6 (18.8)	0.2379
Median blood transfusion (range), mL	0 (0–3600)	0 (0–3600)	0 (0–1200)	0.104	0 (0–3600)	0 (0–800)	0.0693
Pringle maneuver applied, n (%)	52 (41.6)	16 (40)	37 (42.4)	0.803	13 (40.6)	14 (43.8)	0.8474
Median duration of Pringle maneuver when applied (range), min	34 (5–133)	62.5 (30–130)	25.5 (5–133)	**<0.001**	60 (30–130)	20 (14–60)	**0.0020**
Open conversion, n (%)	NA	8 (20)	NA	NA	9 (28.1)	NA	NA
Median postoperative stay (range), d	6 (1–47)	5 (1–26)	6.5 (3–47)	**0.001**	5 (1–26)	7 (4–29)	**0.0354**
Postoperative morbidity, n (%)	36 (28.8)	11 (27.5)	25 (29.4)	0.826	8 (25.0)	11 (34.4)	0.4913
Postoperative major (> G II) morbidity, n (%)	9 (7.2)	3 (7.5)	6 (7.1)	0.929	3 (9.4)	2 (6.5)	0.6547
Postoperative pulmonary complications, n (%)	14 (11.2)	0	14 (16.5)	**0.005**	0 (0.0)	4 (12.50)	**<0.001**
Postoperative 90-day mortality, n (%)	1 (0.8)	0	1 (1.2)	1.000	1 (3.13)	0 (0.0)	1.0000
Reoperation, n (%)	2 (1.6)	2 (5.0)	0	0.101	2 (6.25)	0 (0.0)	0.1573
Close resection margin ≤ 1 mm, n (%)	12 (9.6)	4 (10)	8 (9.4)	1.000	3 (9.4)	5 (15.6)	0.4795
Median closest resection margin, mm (range)	5 (0–60)	5 (0–60)	4 (0–25)	0.269	5 (0–30)	4 (0–20)	0.9909
Microvascular invasion, n (%)	25 (20.0)	7 (17.5)	18 (21.2)	0.632	2 (6.3)	6 (18.8)	0.1573
Tumor grade, n (%)	47 (37.6)	17 (42.5)	30 (35.3)	0.438	11 (34.4)	11 (34.4)	1.0000

Bold values indicate statistically significant $p < 0.05$

patients not surprisingly were more likely to have comorbidities such as cardiac disease, diabetes, hypertension and hyperlipidemia. They were also significantly more likely to have 2 or more comorbidities and have an ASA score ≥ 3. In our experience, it was more difficult for anesthetists to maintain a low central venous pressure in elderly patients during surgery which could be attributed to the higher incidence of comorbidities such as cardiac disease. This together with the frequent presence of liver cirrhosis likely accounted for the increased blood loss and blood transfusion observed with elderly patients undergoing LMH for HCC compared to young patients. Additionally, elderly patients had significantly larger tumors and were significantly more likely to undergo a repeat liver resection for recurrent HCC.

In our experience, comparison between LMH and OMH for elderly patients demonstrated mixed outcomes. LMH was associated with the significantly decreased frequency of pulmonary complications and shorter length of stay at the expense of an increase in blood loss and longer operation time. The increase in blood loss was contrary to previous studies on LMH and OMH for elderly patients which reported either a decrease or no difference in blood loss associated with LMH [1, 2, 13, 20–22]. However, none of these studies focused specifically on LMH for HCC. It is difficult to postulate the reason behind the difference in the results of our study although we postulate that the high complexity of many of the cases in the LMH in this series may have partly attributed to this observation. Forty percent of the 40 patients had resection of tumors in the difficult posterosuperior segments, 37.5% had liver cirrhosis, and 12.5% underwent laparoscopic repeat liver resection for recurrent HCC.

The main limitations of this study are its relatively small sample size and its retrospective nature. Hence, the results comparing LMH and OMH were likely to be affected by some degree of selection bias even after propensity-score matching. This bias can only be eliminated completely by the performance of a prospective randomized controlled trial. Nonetheless, this study represents the first experience in specifically studying the outcomes of LH for HCC in elderly patients to date.

Conclusion

The present study demonstrated that LMH is safe and feasible in elderly patients with HCC. In general, LMH in elderly patients was associated with poorer perioperative outcomes such as longer operation time, increased blood loss and increased length of stay compared to young patients. However, this was not unexpected as elderly patients were significantly more likely to have more comorbidities, larger tumors and repeat liver resections. Comparison between LMH and OMH in elderly patients demonstrated mixed outcomes whereby LMH was associated with decreased pulmonary complications and shorter length of stay at the expense of increased blood loss and longer operation time.

Author contributions BKG and AYC contributed to conception and design, analysis and interpretation of data, drafting of article, final approval, DC contributed to acquisition, analysis and interpretation of data, critical revision, final approval, NS contributed to analysis and interpretation of data, critical revision, JYT, CYC, SYL, PCC and LLO contributed to conception and design, analysis and interpretation of data, critical revision of article, final approval, PRJ contributed to acquisition, analysis and interpretation of data, critical revision of article, final approval, PKC contributed to analysis and interpretation of data, critical revision of article, final approval.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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