Research Article

Benefits of Laparoscopic Liver Resection-A Propensity Score Analysis

Stoeger GJ*, Menzel MM, Jud A, Berlin C, Neeff HP, Kappler C, Fichtner-Feigl S, Holzner PA

Department of General and Visceral Surgery, Center for Surgery, Medical Center-University of Freiburg, Faculty of Medicine, University of Freiburg, Freiburg, Germany

*Corresponding author: Gabriel J Stoeger, Department of General and Visceral Surgery, Center for Surgery, Medical Center-University of Freiburg, Faculty of Medicine, University of Freiburg, Hugstetterstr. 55, D-79106 Freiburg, Germany

Abstract

Background: The history of laparoscopic surgery portrays a success story of how symbiosis of technical advancements and surgical ingenuity has changed surgery fundamentally. The aim of the study was to investigate the surgical outcome of patients undergoing laparoscopic liver resection compared to open liver resection in a single academic center for hepatobiliary surgery. **Materials and Methods:** We retrospectively analysed patients from our in house database who underwent liver surgery for benign or malignant liver disease from 2000 to 2019. We identified 170 cases, which underwent minimally invasive liver resection and conducted a retrospective matched pair analysis using propensity scores. The final group contained 340 cases (148 female and 192 male, age range 18-86 years). To ensure comparability we carried out a nearest neighbour matching. Surgical statistics, complications, and length of hospital stay were evaluated. **Results:** Eventually 81 major (>3 Segments) and 259 minor resections were included. The extent of resection was equally distributed between the two matched groups (p=0.703). We performed more atypical laparoscopic resections than anatomical (p=0.038). The conventional approach showed significantly longer operation times (p<0.001) and a longer length of hospital stay (p<0.001). No difference was found in reported blood transfusions during surgery (p=0.53). Overall, complications were significantly more frequent in the open group (p=0.04), including bile leakage (p=0.021), surgical site infections (p<0.001) and postoperative acute kidney injury (p<0.001). 20 Patients (11.8%) in the laparoscopic group had to undergo conversion to a conventional approach. **Conclusion:** Laparoscopic surgery proved to be a safe and practical technique. Furthermore, we illustrated the development of indications for laparoscopic liver resections over a period of over ten years. With the data indicating a faster recovery of patients combined with current technical advancements of robotic engineering we see the advancement of laparoscopic surgery ensured.

Introduction

Today laparoscopic surgery is well established and partially replaced open surgery for different medical conditions, i.e. appendectomy or cholecystectomy. Initial concerns about feasibility and safety in general were proven wrong and also improvements of surgical outcomes are clearly dislplayed [1-3]. In general and visceral surgery several procedures have shown benefits using a minimally invasive approach, such as antireflux surgery [4], colorectal surgery [5,6], hernia repair [7], adrenal gland surgery [8], splenectomy [9,10], bariatric surgery [11] and hepatic cyst fenestration [12]. In the beginning of laparoscopic liver surgery procedures were limited to cyst fenestration [13], biopsies or limited peripheral resections [14,15]. Owing to growing experience and aspiring intermediate results the portfolio then was expanded to the first laparoscopic anatomical liver resection which were left lateral resections [16,17] followed by left and right hepatectomies [18]. In addition to complete laparoscopic hepatic resection, Hand-Assisted Liver Resections (HALS) [19,20] and hybrid (laparoscopic assisted) liver resections [21] were carried out. Especially in pathologies located in segments 7 and 8 progress was much slower. Primary reservations concerning the feasibility of a laparoscopic approach to those segments have been eliminated in the later years mainly through advances in patient positioning

(semi-prone; left-lateral;) [22,23], altered trocar positioning (i.e. transdiaphragmatic, thoracoscopic approach) [24,25] and a general improvement of surgical skills in this field [26,27]. At present, the complete spectrum of hepatic surgery is offered laparoscopically in specialized, high-volume centers, including Associating Liver Partition with Portal vein Ligation for Staged hepatectomy (ALPPS) [28,29] or concomitant extrahepatic resections (i.e. bile duct resection, lymphadenectomy) [30].

Alongside, laparoscopic surgery had to prove its equality regarding postoperative morbidity, mortality, oncologic safety and other factors [31-34]. Moreover, several distinct benefits of laparoscopic liver surgery came into light. A shorter hospital stay and lower transfusion requirements being among them. Late reports even pointed out a reduced morbidity after laparoscopic liver resection [31,32,35,36]. Especially for elderly [37,38], obese [39,40] or cirrhotic [41,42] patients the laparoscopic approach could yield a better outcome.The aim of the study was to investigate the results of patients undergoing laparoscopic liver resection compared to open resection in a single academic center for hepatobiliary surgery.

Material and Methods

We retrospectively investigated patients of our inhouse database who underwent liver surgery for benign or malignant liver pathologies, dating from 2000 to 2019. We identified 170 cases which underwent minimal invasive liver resection and created a retrospective matched analysis using propensity scores. The final investigation contained 340 cases (148 female and 192 male age range 18-86 years). The propensity score analysis was matched by ASA classification, body mass index, history of liver cirrhosis, extend of resection and malignancy [43]. To ensure comparability we carried out a nearest neighbour matching. Laparoscopic reoperations were allowed as separate cases. In case of conversion or primarily open operations, laparoscopic reoperations were not introduced as separate cases. Cases that were converted to open operations were kept in the laparoscopic group under the intention to treat principle. Hepatic dysfunction was characterized as INR >1.5 and serum bilirubin ≥70 μmol/l [44,45]. History of renal impairment or preexisting elevated serum creatinine >1.2mg/dl (>105.6μmol/l) were assessed preoperatively, as well as history of ascites preoperative. Postoperative Acute Kidney Injury (AKI) as defined in the KIDGO criteria: Increase of serum creatinine by 50 % within 1-7days after surgery or over 0.3mg/dl (≥26.5 μmol/l) within 48 hours or oliguria [46]. Furthermore, postoperative ascites was defined as prolonged fluid secretion and or need for forced diuresis. Surgical stats, non-surgical complications, and Length of Hospital Stay (LOHS) were calculated. All complications were assessed and counted; multiple counts were allowed. Furthermore surgical complications were graded by the most severe using the Dindo classification [47]. All resections were performed by specially trained and qualified hepatobiliary surgeons who regularly perform open and laparoscopic liver resections.

Statistics

All calculations, tables and figures were created with IBM SPSS Statistics 27 (SPSS Inc., Chicago, IL, USA). Continuous variables are shown as median and interquartile range. Categorical variables were investigated with Fisher's-exact-test and are shown as frequencies and percentages. Comparisons between both groups were performed using the Mann-Whitney U-test, the independent t-test for non-connected samples or the Chi-Q test, depending on the distribution and quality. The distribution was assessed using the Kolmogmorov-Smirnov-test. Statistical significance was considered with $P < 0.05$.

Results

The established group of patients underwent surgery between 2000 and 2019 in the university hospital Freiburg, Germany (Table 1). Regarding to the preexisting conditions the laparoscopic group showed a significant higher number of diabetics [36(21.2%) LH vs. 20(11.8%) CH; p=0.019]. Whereas the conventional group showed higher numbers of renal impairment [5(2.9%) LH vs. 23(13.5%) CH; p<0.001] (Table 2).

	(n=340)
Sex f/m	148 /192 43.5% /56.5%
Age (years)	62.15 y, IQR 19.44y
BMI	26.30kg/m^2 IQR 6.31
ASA	3 IQR 1
Benign/malignant	77 /263
	22.6% /77.4%
Cirrhosis (y/n)	81 /259
	23.8% /76.2%
Diabetes mellitus (y/n)	56 /284
	16.5% /83.5%
Renal impairment (y/n)	28 /312
	8.2% /91.8%
Minor/major>3 segments	259 /81
	76.2% /23.8%
Ascites (y/n)	22 /318
	6.5% /93.5%

Table 1: Baseline characteristics. Data is presented as median and interquartile range (25th to 75th percentile) or frequencies and percentages. Sex f/m, Sex female/male; BMI, Body mass index; y/n, yes/no.

	LH (n=170)	CH (n=170)	P value
Sex f/m	77 (45.3%) /93 (54.7 %)	71 (41.8%) /99 (58.2%)	0.512
Age (years)	61.5y (IQR 19.12)	62.85y (IQR 20.23)	0.673
BMI (kg/m^2)	26.67 kg/m^2 (IQR 6.19)	25.9 kg/m^2 IQR 6.43	0.54
ASA-score	3 (IQR 1)	3 (IQR 1)	0.995
Benign/malignant	41 (24.1%) /129 (75.9%)	36 (21.2%) /134 (78.8%)	0.517
Cirrhosis (y/n)	42 (24.7%) /128 (75.3%)	39 (22.9%) /131 (77.1%)	0.703
Diabetes (y/n)	**36 (21.2%) /134 (78.8%)**	**20 (11.8%) /150 (88.2%)**	**0.019**
Renal impairment (y/n)	**5 (2.9%) /165 (97.1%)**	**23 (13.5%) /147 (86.5%)**	**<0.001**
Tumor mass (mm)	30 (IQR 36)	30 (IQR 36)	0.25
Ascites (y/n)	9(5.3%) /161(94.7%)	13(7.6%) /157(92.4%)	0.378

Table 2: Comparison of matched groups. Data is presented as median and interquartile range (25th to 75th percentile) or frequencies and percentages; p<0.05 is considered as significant marked bold. Sex f/m, Sex female/male; BMI, Body mass index; ASA-score, American society of anaesthesiologists-score; y/n, yes/no.

Surgery

The timeframe displayed in this study shows a rapid increase in laparoscopic liver resections after the year 2010 as displayed in Figure 1. In total 81 major resections (>3 Segments) and 259 minor resections were performed. We found an equal distribution between the groups [minor 131(77.1%) LH vs. 128(75.3%) CH; major 39(22.9%) LH vs. 42(24.7%) CH; p= 0.703]. As a result of matching our conventional cohort consisted of more minor anatomical resections compared to the laparoscopic group, which contained more minor atypical resections [anatomical 84(49.4%) LH vs. 103(60.6%) CH; atypical 86(50.6%) LH vs. 67(39.4%) CH; p= 0.038] (Table 3). The postoperative histopathological grading showed similar negative resection margins in the laparoscopic group [R0 160(94.1%) LH vs. 151(88.8%) CH; R1 10(5.9%) LH vs. 19(11.2%) CH; p=0.08] (Table 3). The median duration of the operation showed significant shorter operation time for laparoscopic surgery (204.5 min. LH; IQR 172 vs. 249 min. CH IQR 127; p<0.001) (Table 3). No difference was found in the number of cases in which blood transfusions were administered during surgery [16(9.4%) LH vs. 19(11.2%) CH; p=0.53] (Table 3) The length of hospital stay was significantly longer for patients with conventional approaches (7d IQR 5 LH vs. 11d IQR 6.25 CH; p<0.001) (Table 3).
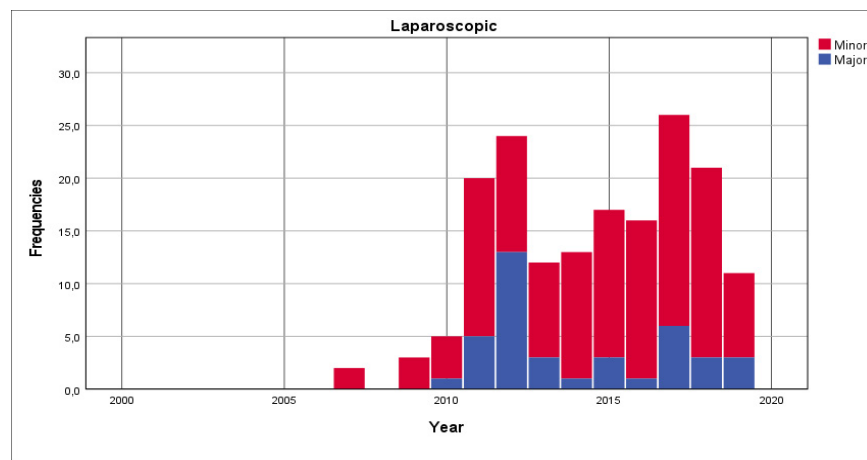

Figure 1: Timeline: Red bar laparoscopic minor liver resections; blue bar laparoscopic major liver resections.

	LH (n=170)	CH (n=170)	P value
Minor/major>3 segment	131(77.1%) /39(22.9%)	128(75.3%) /42(24.7%)	0.703
Anatomical/atypical	**84(49.4%) /86(50.6%)**	**103(60.6%) /67(39.4%)**	**0.038**
R0/R1	160(94.1%) /10(5.9%)	151(88.8%) /19(11.2%)	0.081
Duration (min.)	**204.5 IQR 172**	**249 IQR127**	**<0.001**
Transfusions (y/n)	16(9.4%) /154(90.6%)	19(11.2%) /151(88.8%)	0.53
LOHS	**7 IQR 5**	**11 IQR 6.25**	**<0.001**

Table 3: Operation. Data is presented as median and interquartile range (25th to 75th percentile) or frequencies and percentages; p<0.05 is considered as significant marked bold; min., minute; y/n, yes/no; LHOS, lengths of hospital stay.

Complications

Comparing different degrees of the Dindo classification, the CH group showed a significantly higher amount of I degree complications [9(5.3%) LH vs. 35(21.8%) CH; p<0.001]. The data also shows a significant higher number of IIIa complications [5(2.9%) LH vs. 18(10.6%) CH; p=0.005]. The levels of class IIIb and higher showed no significant differences. Insignificantly more patients died in the conventional group due to septic and cardioembolic complications (Table 4). Overall, the conventional group showed significantly more complications within the DINDO classification [overall 50(29.4%) LH vs. 68(40%) CH (p=0.04)]. Bile leakage occurred in significantly less patients in the laparoscopic group [5(2.9%) LH vs. 15(8.8%) CH; p=0.021] (Table 4). In the conventional group significantly more surgical site infections occurred [6(3.5%) LH vs. 23(13.5%) CH; p< 0.001]. Patients with a conventional approach suffered from postoperative AKI significantly more often (7(4.1%) LH vs. 25(17.7%) CH; p<0.001), of these 32 patients, 18 had a history of renal impairment (Table 2).

20 Patients (11,8%) in the laparoscopic group had to undergo conversion to a conventional approach (Table 4).

	LH (n=170)	CH (n=170)	P value
Complications overall	**50(29.4%)**	**68(40%)**	**0.040**
I	**9(5.3%)**	**35(21.8%)**	**<0.001**
II	19(11.2%)	13(7.6%)	0.265
IIIa	**5(2.9%)**	**18(10.6%)**	**0.005**
IIIb	3(1.8%)	2(1.2%)	0.652
IVa	0	1(0.6%)	0.317
IVb	0	0	1
V	2(1.2%)	4(2.4%)	0.410
Revisions (y/n)	4(2.4%) /166(97.6%)	4(2.4%) /166(97.6%)	1
Bile lekage (y/n)	**5(2.9%) /165(97.1%)**	**15(8.8%) /155(91.2%)**	**0.021**
Bleeding (y/n)	1(0.6%) /169(99.4%)	2(1.2%) /168(98.8%)	0.562
SSI (y/n)	**6(3.5%) /164(96.5%)**	**23(13.5%) /147(86.5%)**	**<0.001**
Abscess (y/n)	0	2(1.2%) /168(98.8%)	0.157
Post OP AKI (y/n)	**7(4.1%) /163(95.9%)**	**25(17.7%) /145(85.3%)**	**<0.001**
Hepatic dysfunction (y/n)	4(2.4%) /166(97.6%)	2(1.2%) /168(98.8%)	0.410

Cholangitis (y/n)	6(3.5%) /164(96.5%)	7(4.1%) /163(95.9%)	0.777
Pneumonia (y/n)	6(3.5%) /164(96.5%)	2(1.2%) /168(98.8%)	0.152
UTI (y/n)	12(7.1%) /158(92.9%)	6(3.5%) /164(96.5%)	0.147
Post OP ascites (y/n)	10(5.9%) /160(94.1%)	14(8.2%) /156(91.8%)	0.397
Conversion (y/n)	20/170 (11.8%)		
Mortality (y/n)	2(1.2%) /168(98.8%)	4(2.4%) /166(97.6%)	0.410

Table 4: Complications. Data is presented as median and interquartile range (25th to 75th percentile) or frequencies and percentages; p<0.05 is considered as significant marked bold; Dindo classification grade I-V; y/n, yes/no; SSI, surgical site infection; Post OP AKI, post OP acute kidney injury; UTI, urinary tract infection.

Discussion

The advance and the technical achievements of laparoscopic surgery made it one of the fastest growing and rapidly developing fields in surgery. In the case of hepatobiliary surgery, laparoscopic resection for instance of the left lateral segment has quickly become the gold standard treatment [48-52]. The metabolic complexity of the hepatic system in combination with the pathology of the underlying diseases presents a particular challenge for the performing surgeon. Nevertheless, studies have shown a fast-learning curve and the fast expansion of resection size [53,54]. Minor resections are responsible for the successful start of minimal invasive liver surgery, with it shortly becoming a routine operation [55-57]. The location of the mass plays an essential role in the development of the surgical treatment plan. Masses in so called "non laparoscopic" segments posterior and superior in the liver prove to be challenging. Lesions located in these segments are proven to be associated with higher conversion rates, prolonged operation time, higher blood loss and narrow surgical margins [27,55,58-60]. An individual evaluation of strategy and risk management as well as the use of specialized techniques like assisted laparoscopy are a possible answer to the challenges [55]. The conversion rate in this study of 11,8% was within published range of 0% - 20% [55,61]. In our analysis, we chose to leave laparoscopically scheduled but converted patients in the laproscopic group, following the intention to treat principle, to see how conversion would affect the surgical statistics. Large European and Asian studies analyzing explicitly converted cases have shown that unplanned conversions have a worse perioperative outcome but no significant difference in complications compared with planned open liver resections [62,63]. Our laparoscopic group does not support this trend with on anverage shorter operation times and fewer complications. Supporting the thesis of benefits of laparoscopic surgery even with the intention to treat priciple and the inclusion of converted patients in the laparoscopic group.

At our centre an increase of laparoscopic hepatobiliary surgery occurred after the year 2010. The numbers in this study seem to be in average fair comparison to other national and international study population. Large series have been published after the year 2010 as international reviews formed combined collectives [35,64]. With these studies the problem of indication and choice of the different surgical approaches cannot be addressed. The bias of preferring conventional surgery in difficult cases can in our opinion never be completely ruled out. Large groups and retrospective data can provide an estimate of the developments in addition to the possibility of reviewing the current standards. However, to date, there is no uniform guideline for surgical approaches. Most of the series published, derive from retrospective data. Reasons of complexity and time sensitivity seem to make large, randomised studies unpractical. This might be one of the reasons for the wider use of propensity score analysis [31,65]. The rather complex tool was developed during the 1990ties to minimize bias while observing causal effects in retrospective data [66,67]. In this study we were able to show a significant shorter operation time in the laparoscopic group, with no significant difference in resection size. These findings are in concert with numerous European, Asian, and American studies [55,56,68-71]. One explanation can possibly be found in the time spared for the laparotomy and abdominal wall closure. Furthermore, a laparoscopic approach was shown to be safe and even favourable in major resections concerning a reduced rate of blood loss, fewer complications and a shorter length of hospital stay [55,56,68-71].

Despite more anatomical resections in the conventional group our data showed a higher rate of bile leakage. Bile leakage is one of the most common specific complication in hepatobiliary surgery. The positive pressure of the pneumoperitoneum and the better exposure in laparoscopy could be an explanation for fewer bile leakages. Large series have shown fewer complications in laparoscopically operated patients [61,72]. Other retrospective studies reported no significant difference in bile leakage [52,64]. A recent study investigated the influence of different devices for transection. The authors found no significant difference between a cavitron ultrasonic surgical aspirator and a bipolar device (CUSA vs. Ligasure) [73]. A recent systematic review containing lager

series of open hepatectomies dating back until 2001 found the bipolar cautery to be the best device to prevent blood loss and the harmonic scalpel to have the least overall and major complications [74]. There is a myriad of different studies introducing new energy devices in rather small groups [75-77]. With the lack of large prospective randomised trials, the question of the right device remains controversial. On the other hand, the diversity of devices can be seen as an important asset. In lack of comprehensive clinical data our in-house standard used a CUSA for almost all conventional liver resections and either the Ligasure or Harmonic device in laparoscopic surgery. In cirrhotic liver parenchyma we preferred the Harmonic device.

Complications wise the two groups were in fair comparison. A clear trend of more minor complications Dindo I and IIIa and more overall complications in the conventional group can be shown. We found more cases of postoperative AKI, which may be caused by intraoperative volume management, hypotension, and the preexisting conditions. Other large studies did not show these findings mostly for not explicitly displaying the data. Overall complications in the laparoscopic groups were lower or equal to the conventional groups [31,52,61,64]. The conventional group showed significantly more surgical site infections. These findings are in concert with other authors [55,61].

Major complications did not differ significantly in our cases. The number of in hospital mortality, due to septic complications in relation to surgery showed a slightly higher number of conventional treated patients. A review of large series by Nguyen et al. published an overall morbidity rate of 10,5% (range from 0%-50%) for laparoscopic liver resections [78]. Jackson et al. found no significant differences in comparison between the groups [61]. There are no studies indicating clear inferiority of laparoscopic resections. The overall length of hospital stays, which is an important economic factor showed a significant longer stay for conventional operated patients. Other studies show similar or equal durations. Furthermore, different authors clearly described a superiority of laparoscopic operations in matters of wound pain in connection with the surgical management and length of hospital stay [64,79]. In addition to economic factors and a smaller wound area, biopsychosocial factors that can accelerate discharge should not be ignored. A large metanalysis concerning Enhanced Recovery (ERAS) after liver surgery showed a significant shorter length of hospital stay and lower complication rates in the laparoscopic and conventional ERAS groups compared to standard care. In the subgroup analysis laparoscopic patients even showed significantly lower complications rates compared to standard treatment. A trend that could not be shown in conventional ERAS patients [80].

Limitation

A clear limitation of this study is the retrospective design.

Concerns about different training- and skill-levels of surgeons and personal preferences can also not be fully addressed in this setting.

Conclusion

Laparoscopic surgery proved to be a safe and practical method of operation. Our study provides another comparison of LH vs. CH operation technique and depicted the advancement and development of indications in laparoscopic liver resections in over a decade in a relatively large population. Overall, we found, a better recovery. In our opinion, there is no doubt that technological progress and robotic engineering will ensure the further development of laparoscopic surgery in this field in the future. In concert with the current publications, we believe that major laparoscopic resections or laparoscopic resections in less exposed areas should be performed in high volume centers. The introduction of large nationwide registries for quality control could provide a better orientation.

References

1. Ukai T, Shikata S, Takeda H, Dawes L, Noguchi Y, et al. (2016) Evidence of surgical outcomes fluctuates over time: results from a cumulative meta-analysis of laparoscopic versus open appendectomy for acute appendicitis. BMC gastroenterology 16: 37.

2. Yu MC, Feng YJ, Wang W, Fan W, Cheng HT, et al. (2017) Is laparoscopic appendectomy feasible for complicated appendicitis ?A systematic review and meta-analysis. International journal of surgery (London, England) 40: 187-197.

3. Keus F, Gooszen HG, van Laarhoven CJ (2010) Open, small-incision, or laparoscopic cholecystectomy for patients with symptomatic cholecystolithiasis. An overview of Cochrane Hepato-Biliary Group reviews. The Cochrane database of systematic reviews 2010: Cd008318.

4. Hakanson BS, Thor KB, Thorell A, Ljungqvist O (2007) Open vs laparoscopic partial posterior fundoplication. A prospective randomized trial. Surg Endosc 21: 289-298.

5. Fujii S, Tsukamoto M, Fukushima Y, Shimada R, Okamoto K, et al. (2016) Systematic review of laparoscopic vs open surgery for colorectal cancer in elderly patients. World journal of gastrointestinal oncology 8: 573-582.

6. Di B, Li Y, Wei K, Xiao X, Shi J, et al. (2013) Laparoscopic versus open surgery for colon cancer: a meta-analysis of 5-year follow-up outcomes. Surgical oncology 22: e39-43.

7. Wu JJ, Way JA, Eslick GD, Cox MR (2018) Transabdominal Pre-Peritoneal Versus Open Repair for Primary Unilateral Inguinal Hernia: A Meta-analysis. World J Surg 42: 1304-1311.

8. Hazzan D, Shiloni E, Golijanin D, Jurim O, Gross D, et al. (2001) Laparoscopic vs open adrenalectomy for benign adrenal neoplasm. Surg Endosc 15: 1356-1358.

9. Al-raimi K, Zheng SS (2016) Postoperative outcomes after open splenectomy versus laparoscopic splenectomy in cirrhotic patients: a meta-analysis. Hepatobiliary & pancreatic diseases international : HBPD INT 15: 14-20.

10. Feldman LS, Demyttenaere SV, Polyhronopoulos GN, Fried GM (2008) Refining the selection criteria for laparoscopic versus open splenectomy for splenomegaly. Journal of laparoendoscopic & advanced surgical techniques. Part A 18: 13-19.

11. Reoch J, Mottillo S, Shimony A, Filion KB, Christou NV, et al. (2011) Safety of laparoscopic vs open bariatric surgery: a systematic review and meta-analysis. Archives of surgery (Chicago, Ill. : 1960) 146: 1314-1322.

12. Zhang JY, Liu Y, Liu HY, Chen L, Su DW, et al. (2018) Comparison of the Recurrence Rates of Nonparasitic Hepatic Cysts Treated With Laparoscopy or With Open Fenestration: A Meta-Analysis. Surgical laparoscopy, endoscopy & percutaneous techniques 28: 67-72.

13. Morino M, De Giuli M, Festa V, Garrone C (1994) Laparoscopic management of symptomatic nonparasitic cysts of the liver. Indications and results. Annals of surgery 219: 157-164.

14. Reich H, McGlynn F, DeCaprio J, Budin R (1991) Laparoscopic excision of benign liver lesions. Obstetrics and gynecology 78: 956-958.

15. Katkhouda N, Fabiani P, Benizri E, Mouiel J (1992) Laser resection of a liver hydatid cyst under videolaparoscopy. The British journal of surgery 79: 560-561.

16. Azagra JS, Goergen M, Gilbart E, Jacobs D (1996) Laparoscopic anatomical (hepatic) left lateral segmentectomy-technical aspects. Surg Endosc 10: 758-761.

17. Kaneko H, Takagi S, Shiba T (1996) Laparoscopic partial hepatectomy and left lateral segmentectomy: technique and results of a clinical series. Surgery 120: 468-475.

18. Huscher CG, Lirici MM, Chiodini S, Recher A (1997) Current position of advanced laparoscopic surgery of the liver. Journal of the Royal College of Surgeons of Edinburgh 42: 219-225.

19. Fong Y, Jarnagin W, Conlon KC, DeMatteo R, Dougherty E, et al. (2000) Hand-assisted laparoscopic liver resection: lessons from an initial experience. Archives of surgery (Chicago, Ill. : 1960) 135: 854-859.

20. Huang MT, Lee WJ, Wang W, Wei PL, Chen RJ (2003) Hand-assisted laparoscopic hepatectomy for solid tumor in the posterior portion of the right lobe: initial experience. Annals of surgery 238: 674-679.

21. Koffron AJ, Kung RD, Auffenberg GB, Abecassis MM (2007) Laparoscopic liver surgery for everyone: the hybrid method. Surgery 142: 463-468.

22. Ikeda T, Yonemura Y, Ueda N, et al. (2011) Pure laparoscopic right hepatectomy in the semi-prone position using the intrahepatic Glissonian approach and a modified hanging maneuver to minimize intraoperative bleeding. Surgery today 41: 1592-1598.

23. Belli G, Fantini C, D'Agostino A, et al. (2008) Laparoscopic segment VI liver resection using a left lateral decubitus position: a personal modified technique. Journal of gastrointestinal surgery : official journal of the Society for Surgery of the Alimentary Tract 12: 2221-2226.

24. Ogiso S, Conrad C, Araki K, Nomi T, Anil Z, et al. (2015) Laparoscopic Transabdominal With Transdiaphragmatic Access Improves Resection of Difficult Posterosuperior Liver Lesions. Annals of surgery 262: 358-365.

25. Schwarz L, Aloia TA, Eng C, Chang GJ, Vauthey JN, et al. (2016) Transthoracic Port Placement Increases Safety of Total Laparoscopic Posterior Sectionectomy. Annals of surgical oncology 23: 2167.

26. Dulucq JL, Wintringer P, Stabilini C, Mahajna A (2006) Isolated laparoscopic resection of the hepatic caudate lobe: surgical technique and a report of 2 cases. Surgical laparoscopy, endoscopy & percutaneous techniques 16: 32-35.

27. Cho JY, Han HS, Yoon YS, Shin SH (2008) Feasibility of laparoscopic liver resection for tumors located in the posterosuperior segments of the liver, with a special reference to overcoming current limitations on tumor location. Surgery 144: 32-38.

28. Cai X, Peng S, Duan L, Wang Y, Yu H, et al. (2014) Completely laparoscopic ALPPS using round-the-liver ligation to replace parenchymal transection for a patient with multiple right liver cancers complicated with liver cirrhosis. Journal of laparoendoscopic & advanced surgical techniques. Part A 24: 883-886.

29. Machado MA, Makdissi FF, Surjan RC (2012) Totally laparoscopic ALPPS is feasible and may be worthwhile. Annals of surgery 256: e13.

30. Machado MA, Makdissi FF, Surjan RC, Mochizuki M (2012) Laparoscopic resection of hilar cholangiocarcinoma. Journal of laparoendoscopic & advanced surgical techniques. Part A 22: 954-956.

31. Zhang XL, Liu RF, Zhang D, Zhang YS, Wang T (2017) Laparoscopic versus open liver resection for colorectal liver metastases: A systematic review and meta-analysis of studies with propensity score-based analysis. International journal of surgery 44: 191-203.

32. Cheng Y, Zhang L, Li H, Wang L, Yiming Huang Y, et al. (2017) Laparoscopic versus open liver resection for colorectal liver metastases: a systematic review. The Journal of surgical research 220: 234-246.

33. Zhou Y, Xiao Y, Wu L, Li B, Li H (2013) Laparoscopic liver resection as a safe and efficacious alternative to open resection for colorectal liver metastasis: a meta-analysis. BMC surgery 13: 44.

34. Berardi G, Van Cleven S, Fretland AA, Barkhatov L, Halls M, et al. (2017) Evolution of Laparoscopic Liver Surgery from Innovation to Implementation to Mastery: Perioperative and Oncologic Outcomes of 2,238 Patients from 4 European Specialized Centers. J Am Coll Surg 225: 639-649.

35. Ciria R, Cherqui D, Geller DA, Briceno J, Wakabayashi G (2016) Comparative Short-term Benefits of Laparoscopic Liver Resection: 9000 Cases and Climbing. Annals of surgery 263: 761-777.

36. Tian ZQ, Su XF, Lin ZY, Wu MC, Wei LX, et al. (2016) Meta-analysis of laparoscopic versus open liver resection for colorectal liver metastases. Oncotarget 7: 84544-84555.

37. Chen K, Pan Y, Maher H, Zhang B, Zheng XY (2018) Laparoscopic hepatectomy for elderly patients: Major findings based on a systematic review and meta-analysis. Medicine 97: e11703.

38. Goh BKP, Chua D, Syn N, Teo JY, Chan CY, et al (2018) Perioperative Outcomes of Laparoscopic Minor Hepatectomy for Hepatocellular Carcinoma in the Elderly. World J Surg 2018.

39. Toriguchi K, Hatano E, Sakurai T, Seo S, Taura K, et al. (2015) Laparoscopic liver resection in obese patients. World J Surg 39: 1210-1215.

40. Uchida H, Iwashita Y, Saga K, Takayama H, Watanabe K, et al. (2016) Benefit of laparoscopic liver resection in high body mass index patients. World journal of gastroenterology 22: 3015-3022.

41. Twaij A, Pucher PH, Sodergren MH, Gall T, Darzi A, et al. (2014) Laparoscopic vs open approach to resection of hepatocellular carcinoma in patients with known cirrhosis: systematic review and meta-analysis. World journal of gastroenterology 20: 8274-8281.

42. Goh EL, Chidambaram S, Ma S (2018) Laparoscopic vs open hepatectomy for hepatocellular carcinoma in patients with cirrhosis: A meta-analysis of the long-term survival outcomes. International journal of surgery (London, England) 50: 35-42.

43. Daabiss M (2011) American Society of Anaesthesiologists physical status classification. Indian journal of anaesthesia 55: 111-115.

44. Mochida S, Takikawa Y, Nakayama N, et al. (2011) Diagnostic criteria of acute liver failure: A report by the Intractable Hepato-Biliary Diseases Study Group of Japan. Hepatology research : the official journal of the Japan Society of Hepatology 41: 805-812.

45. Wlodzimirow KA, Eslami S, Abu-Hanna A, Nieuwoudt M, Chamuleau RA (2012) Systematic review: acute liver failure - one disease, more than 40 definitions. Alimentary pharmacology & therapeutics 35: 1245-1256.

46. Ostermann M, Bellomo R, Burdmann EA, et al. (2020) Controversies in acute kidney injury: conclusions from a Kidney Disease: Improving Global Outcomes (KDIGO) Conference. Kidney Int 98: 294-309.

47. Dindo D, Demartines N, Clavien PA (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Annals of surgery 240: 205-213.

48. Ratti F, Barkhatov LI, Tomassini F, Cipriani F, Kazaryan AM, et al. (2016) Learning curve of self-taught laparoscopic liver surgeons in left lateral sectionectomy: results from an international multi-institutional analysis on 245 cases. Surgical endoscopy 30: 3618-3629.

49. Morise Z, Wakabayashi G (2017) First quarter century of laparoscopic liver resection. World journal of gastroenterology : WJG 23: 3581-3588.

50. Kaneko H, Otsuka Y, Kubota Y, Wakabayashi G (2017) Evolution and revolution of laparoscopic liver resection in Japan. Ann Gastroenterol Surg 1: 33-43.

51. Hibi T, Cherqui D, Geller DA, Itano O, Kitagawa Y, et al. (2016) Expanding indications and regional diversity in laparoscopic liver resection unveiled by the International Survey on Technical Aspects of Laparoscopic Liver Resection (INSTALL) study. Surgical endoscopy 30: 2975-2983.

52. Macacari RL, Coelho FF, Bernardo WM, Kruger JAP, Jeismann VB, et al. (2019) Laparoscopic vs. open left lateral sectionectomy: An update meta-analysis of randomized and non-randomized controlled trials. International journal of surgery 61: 1-10.

53. Di Sandro S, Bagnardi V, Najjar M, Buscemi V, Lauterio A, et al. (2018) Minor laparoscopic liver resection for Hepatocellular Carcinoma is safer than minor open resection, especially for less compensated cirrhotic patients: Propensity score analysis. Surgical oncology 27: 722-729.

54. Guilbaud T, Birnbaum DJ, Berdah S, Farges O, Beyer Berjot L (2019) Learning Curve in Laparoscopic Liver Resection, Educational Value of Simulation and Training Programmes: A Systematic Review. World journal of surgery 43: 2710-2719.

55. Coelho FF, Kruger JA, Fonseca GM, et al. (2016) Laparoscopic liver resection: Experience based guidelines. World journal of gastrointestinal surgery 8: 5-26.

56. Buell JF, Cherqui D, Geller DA, Araújo RLC, Jeismann VB, et al. (2009) The international position on laparoscopic liver surgery: The Louisville Statement, 2008. Annals of surgery 250: 825-830.

57. Belli G, Gayet B, Han HS, Wakabayashi G, Kim KH, et al. (2013) Laparoscopic left hemihepatectomy a consideration for acceptance as standard of care. Surgical endoscopy 27: 2721-2726.

58. Troisi RI, Montalti R, Van Limmen JG, Cavaniglia D, Reyntjens K, et al. (2014) Risk factors and management of conversions to an open approach in laparoscopic liver resection: analysis of 265 consecutive cases. HPB : the official journal of the International Hepato Pancreato Biliary Association 16: 75-82.

59. Kazaryan AM, Rosok BI, Marangos IP, Rosseland AR, Edwin B (2011) Comparative evaluation of laparoscopic liver resection for posterosuperior and anterolateral segments. Surgical endoscopy 25: 3881-3889.

60. Ishizawa T, Gumbs AA, Kokudo N, Gayet B (2012) Laparoscopic segmentectomy of the liver: from segment I to VIII. Annals of surgery 256: 959-964.

61. Jackson NR, Hauch A, Hu T, Buell JF, Slakey DP, et al. (2015) The safety and efficacy of approaches to liver resection: a meta-analysis. JSLS : Journal of the Society of Laparoendoscopic Surgeons / Society of Laparoendoscopic Surgeons 19: e2014 00186.

62. Lee JY, Rho SY, Han DH, Choi JS, Choi GH (2020) Unplanned conversion during minimally invasive liver resection for hepatocellular carcinoma: risk factors and surgical outcomes. Annals of surgical treatment and research 98: 23-30.

63. Cauchy F, Fuks D, Nomi T, L Schwarz, L Barbier, et al. (2015) Risk factors and consequences of conversion in laparoscopic major liver resection. The British journal of surgery 102: 785-795.

64. Assis BS, Coelho FF, Jeismann VB, Kruger JAP, Fonseca GM, et al. (2020) Total laparoscopic vs. open liver resection: comparative study with propensity score matching analysis. Arquivos brasileiros de cirurgia digestiva : ABCD = Brazilian archives of digestive surgery 33: e1494.

65. Wabitsch S, Kästner A, Haber PK, Benzing C, Krenzien F, et al. (2019) Laparoscopic Versus Open Liver Resection for Benign Tumors and Lesions: A Case Matched Study with Propensity Score Matching. Journal of laparoendoscopic & advanced surgical techniques. Part A 29: 1518-1525.

66. ROSENBAUM PR, RUBIN DB (1983) The central role of the propensity score in observational studies for causal effects. Biometrika 70: 41-55.

67. Pattanayak CW, Rubin DB, Zell ER (2011) [Propensity score methods for creating covariate balance in observational studies]. Rev Esp Cardiol 64: 897-903.

68. Dokmak S, Raut V, Aussilhou B, Ftériche FS, Farges O, et al. (2014) Laparoscopic left lateral resection is the gold standard for benign liver lesions: a case-control study. HPB : the official journal of the International Hepato Pancreato Biliary Association 16: 183-187.

69. Kim Y, Amini N, He J, Margonis GA, Weiss M, et al. (2015) National trends in the use of surgery for benign hepatic tumors in the United States. Surgery 157: 1055-1064.

70. Mostaedi R, Milosevic Z, Han HS, Khatri VP (2012) Laparoscopic liver resection: Current role and limitations. World journal of gastrointestinal oncology 4: 187-192.

71. Belli G, Gayet B, Han HS, Wakabayashi G, Kim KH, et al. (2013) Laparoscopic left hemihepatectomy a consideration for acceptance as standard of care. Surgical endoscopy 27: 2721-2726.

72. Mirnezami R, Mirnezami AH, Chandrakumaran K, Hilal MA, Pearce NW, et al. (2011) Short- and long-term outcomes after laparoscopic and open hepatic resection: systematic review and meta-analysis. HPB : the official journal of the International Hepato Pancreato Biliary Association 13: 295-308.

73. Liu F, Wei Y, Li H, Wang WT, Wen TF, et al. (2018) LigaSure versus CUSA for parenchymal transection during laparoscopic hepatectomy in hepatocellular carcinoma patients with cirrhosis: a propensity score-matched analysis. Surgical endoscopy 32: 2454-2465.

74. Kamarajah SK, Wilson CH, Bundred JR, Lin A, Sen G, et al. (2020) A systematic review and network meta analysis of parenchymal transection techniques during hepatectomy: an appraisal of current randomised controlled trials. HPB : the official journal of the International Hepato Pancreato Biliary Association 22: 204-214.

75. Badawy A, Seo S, Toda R, Fuji H, Ishii T, et al. (2018) Evaluation of a new energy device for parenchymal transection in laparoscopic liver resection. Asian J Endosc Surg 11: 123-128.

76. Dural C, Akyuz M, Yazici P, Aksoy E, Aucejo F, et al. (2016) Safety and Efficacy of a New Bipolar Energy Device for Parenchymal Dissection in Laparoscopic Liver Resection. Surgical laparoscopy, endoscopy & percutaneous techniques 26: 21-24.

77. Iida H, Naka S, Tani M (2019) Feasibility of a new microwave energy-based scissors device for hepatectomy. Asian journal of surgery / Asian Surgical Association 42: 849-851.

78. Nguyen KT, Gamblin TC, Geller DA (2009) World review of laparoscopic liver resection-2,804 patients. Annals of surgery 250: 831-841.

79. Aldrighetti L, Guzzetti E, Pulitanò C, Cipriani F, Marco Catena M, et al. (2010) Case-matched analysis of totally laparoscopic versus open liver resection for HCC: short and middle term results. Journal of surgical oncology 102: 82-86.

80. Noba L, Rodgers S, Chandler C, Balfour A, Hariharan D, et al. (2020) Enhanced Recovery After Surgery (ERAS) Reduces Hospital Costs and Improve Clinical Outcomes in Liver Surgery: a Systematic Review and Meta-Analysis. Journal of gastrointestinal surgery : official journal of the Society for Surgery of the Alimentary Tract 24: 918-932.