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Laparoscopic parenchymal-sparing liver resection of lesions in the central segments: feasible, safe, and effective

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Abstract

Introduction Here we report the first systematic evaluation of laparoscopic parenchymal-sparing segmentectomies for the resection of lesions in the central liver segments and the first series of laparoscopic mesohepatectomies.

Patients and Methods From 1995 to 2012, 482 laparoscopic hepatectomies were performed. Thirty-two patients underwent isolated resection of IVa and VIII, bisegmentectomies of IVa/IVb and V/VIII, or mesohepatectomy. Sixteen isolated resections of IVb or V were excluded. Data was extracted from a retrolective database and chart review. Complications were classified (Clavien–Dindo) by three independent surgeons. Seventeen patients had colorectal liver metastasis, four had neuroendocrine tumors, five had hepatocellular carcinoma, two had GIST, and one each had esophageal cancer, breast cancer, and melanoma. Fifteen patients underwent anatomic- and 17 non-anatomic wedge resection. Average blood loss was 403 cc (SD 475), and overall operative time was 183 (SD 106) for hepatectomy and 253 min (SD 94) for mesohepatectomies. Major complications were mainly attributable to synchronous procedures. Mortality, transfusion, and morbidity rates were 0, 12, and 37 %, respectively.

Conclusion Parenchymal-sparing laparoscopic central liver resections and mesohepatectomies are feasible, safe, and effective if specific technical details we have learned over time are considered. Concomitant procedures should be an exception. This approach exhibits an alternative to open surgery while avoiding unnecessary sacrifice of functional parenchyma.

Keywords Laparoscopic liver resection · Laparoscopic hepatectomy · Mesohepatectomy · Colorectal metastasis · Central liver resection · Synchronous liver resection

Laparoscopic hepatic resections have garnered increasing interest in the hepatobiliary surgical community [1–3]. Although the advantages of laparoscopic hepatic resection versus open surgery in the perioperative period (e.g., less blood loss, fewer complications, and shorter duration of hospitalization) are well recognized, emerging evidence suggests that this approach might have long-term oncologic benefits as well [4]. However, the technically challenging nature of laparoscopic liver surgery and concerns about the ability to achieve R0 margins for malignant lesions have thus far limited its widespread use in liver surgery. A laparoscopic approach to lesions in the central liver segments IV, V, and VIII via segmentectomy or lesions necessitating mesohepatectomy (removal of segments IV, V, and VIII, also known as central hepatectomy) has traditionally been considered contraindicated owing to difficult exposure of critical anatomic structures and challenging laparoscopic control of inflow and outflow while preserving supply to the adjacent segments II, III, VI, and VII.

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Parenchymal-sparing central liver resection was reported for the first time by McBride and Wallace in 1972 with mortality of every third patient in their series. Recent reports confirm that despite recent advances in anatomic understanding and operative techniques, managing these lesions even via an open parenchymal-sparing approach of segmentectomy or mesohepatectomy rather than extended lobectomies remains very challenging, and few reports exist today [5–11]. We reported the first total laparoscopic central hepatectomy in 2008 [12], another group reported a laparoscopic central bisegmentectomy for hepatocellular carcinoma (HCC) in 2009, and Machado and Kalil reported an entirely laparoscopic central hepatectomy using an intrahepatic Glissonian technique in 2011 [13, 14]. All case reports thus far, including our previous publication, have not gone beyond reporting that parenchymal-sparing management of centrally located liver lesions is technically possible. What remains to be determined is whether such an approach proves to be feasible and more importantly safe in a larger cohort and whether evidence can be obtained that the oncologic outcome is comparable to open or non-parenchymal-sparing techniques.

We herein performed a retrospective analysis to assess the safety and feasibility of laparoscopic liver resections of lesions located in the central liver segments and laparoscopic mesohepatectomies. This report is the first systematic evaluation of laparoscopic resection of lesions in the central liver segments and also the first reported series of complete mesohepatectomies. An educational video on laparoscopic mesohepatectomy highlighting the technical details using indocyanine green counterstaining and near-infrared vision has been provided in the supplementary section.

Patients and methods

The study cohort was retrospectively identified from the prospectively maintained liver surgery database of Paris Descartes University (Paris, France), after institutional approval. From 1995 to 2012, 482 laparoscopic hepatectomies were performed in a specialized center focusing on hepatobiliary surgery. Thirty-two patients matched the search criteria of a lesion requiring either an isolated resection of IVa and VIII, bisegmentectomy of IVa/IVb and V/VIII, or mesohepatectomy (IVa, IVb, V, and VIII) (Fig. 1A, B). Segments were defined according to the International Hepato-Pancreato-Biliary Association terminology (Brisbane 2000 nomenclature) derived from Couinaud's classification [15]. Isolated laparoscopic resections of segment IVb or V (16 identified cases) were excluded from the analysis owing to the comparatively easy laparoscopic removal of these anterior-inferior lesions. Patient selection for laparoscopic resection of the centrally located lesions was based on consensus review of the patient chart and especially axial imaging (CT and MRI) at an Interdisciplinary Tumor Board. Patients with IVC involvement were excluded from this study. None of the patients required portal vein embolization due to sufficient future liver remnant due to the planned parenchymal-sparing approach. Complications were classified according to the Dindo–Clavien grading system [17]. De-identified patient

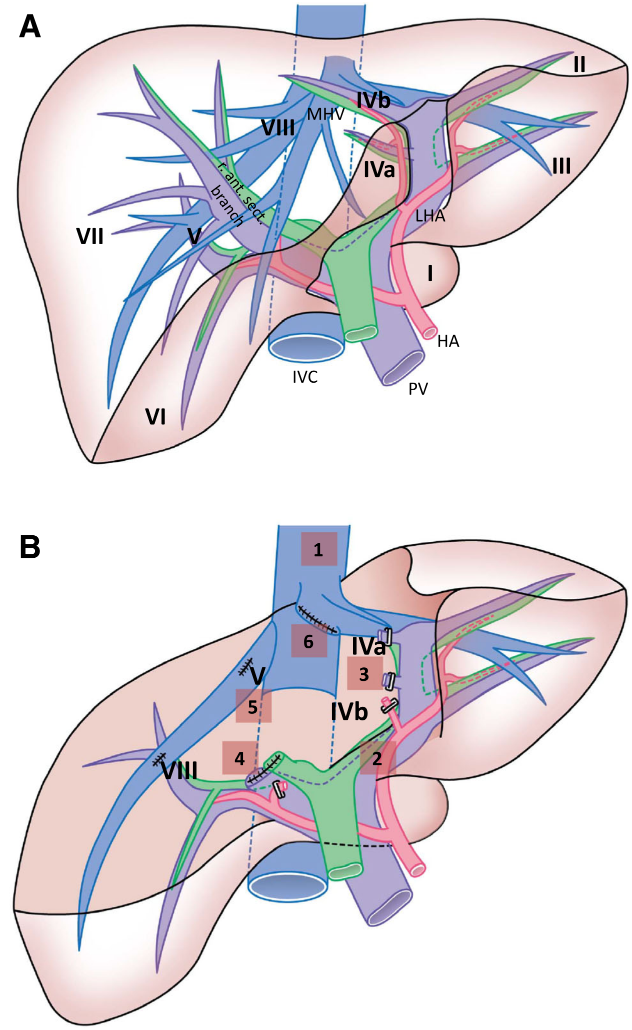

Fig. 1 Critical anatomy for total laparoscopic mesohepatectomy. **A** Mesohepatectomy leads to removal of segments IV, V, and VIII, while segments II, III, VI, and VII remain. **B** The numbers indicate the operative steps. After dissection of the triangular ligament (*1*) the portal branches to segments IVb and IVa (*3*) are divided as well as the medial branch of the left hepatic artery (*2*). After complete parenchymal division between the left lateral and left medial sector, the anterior sectoral branch is approached via a Glissonian approach (*4*). Here we need to ensure that the posterior sectoral branch is preserved. After division of the right portal fissure branches to segments V (*4*) and VIII (*5*) and the middle hepatic vein are divided (*6*). Please see the video and the supplemental material section for detailed explanation

data were extracted by three independent surgeons. In cases of discrepancy with respect to data extraction, the individual case was discussed in detail with all members of the research team as well as the gastroenterology service not directly involved in the research but involved in the care of patients undergoing laparoscopic liver resection. Statistical analysis was performed using Microsoft Excel 2007.

Techniques

General technical considerations for laparoscopic surgery of centrally located lesions

Detailed preoperative axial imaging is critical for laparoscopic surgery for lesions in SIV, V, and VIII, and the relationship between the lesion and vascular and biliary structures must be clearly delineated preoperatively and remain readily available during surgery. Thereby, special attention needs to be given to the SVIII venous branch as well as the anterior portal pedicle, which will become critical during the parenchymal transsection. Preoperative antibiotic and thrombosis prophylaxis are administered. Special equipment is necessary and includes an atraumatic liver retractor, a harmonic parenchymal transsection device, laparoscopic linear staplers with a vascular load, and a flexible ultrasound probe with Doppler capabilities. A laparotomy set and a hand port should be readily available should urgent conversion become necessary. An orogastric tube should be placed, and a preoperative discussion with the anesthesia team regarding low central venous pressures during the surgery is critical. The volume status can be confirmed with laparoscopic ultrasound probe at the beginning of the case: the inferior vena cava should exhibit measureable respiratory variations and be easily compressible with the probe. The patient is placed on the operating table in a slightly reversed Trendelenburg and lithotomy position, with the arms tucked and the legs separated in a low 90° angle to allow maximum freedom of movements with the instruments during surgery. The upper body is strapped down to avoid sliding during Trendelenburg positioning while avoiding stretch on the brachial plexus. The mounting device for the liver retractor is secured on the operating table.

Specific technical considerations for a total laparoscopic mesohepatectomy

Please see the educational video in the supplemental material section explaining the anatomic challenges and operative tactics of a total laparoscopic mesohepatectomy. After establishing a pneumoperitoneum of 12 mmHg, the first trocar is placed approximately one-third of the distance between costal margin and umbilicus in the third closest to the umbilicus and half-way between the midclavicular line and midline (Fig. 2A, B). After inspecting for carcinomatosis, a second trocar (12 mm), which can be used for stapling and ultrasound, is placed at the costal margin in a line between the first trocar and the umbilicus. A complete liver ultrasound should be performed after inspection for carcinomatosis to assess the lesion's relationship to vascular structures and to exclude additional lesions in the future liver remnant. Then, additional 5-mm trocars are placed with optimal triangulation to the lesion, as well as optimization of eye-target-monitor axis. The liver inflow through the porta can be controlled with umbilical tape placed around the porta should a later Pringle maneuver become necessary. The suspensory

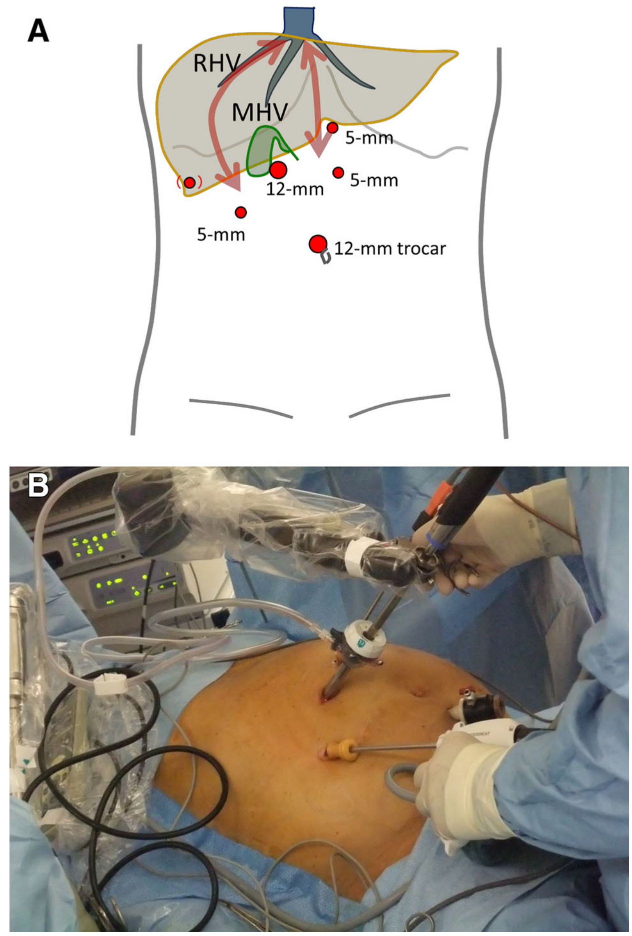

Fig. 2 Port and patient positioning for total laparoscopic mesohepatectomy. **A** The two 12-mm trocars can be used for ultrasound and camera. The two lower 5-mm ports and the 12-mm port at umbilicus are used for the dissection at the level of the porta. The upper 5-mm ports and 12-mm port are used for completing the parenchymal transection and controlling the drainage of the middle hepatic vein into the IVC. **B** The patient is in the French position with the operating surgeon between the legs for optimal eye-target-monitor axis

Table 1 Demographics, pathology and surgical parameters

Demographics	
Total patients	32
Male	19
Female	13
Average age	61
Range	29–87
Standard deviation	14.3
Tumor entity	
Colorectal liver metastasis	17
Neuroendocrine tumor	4
Hepatocellular carcinoma (HCC)	5
Gastrointestinal stroma tumor (GIST)	2
Esophageal cancer	1
Melanoma	1
Breast cancer	1
Surgical parameters	
Metachronous metastasis	15
Synchronous	11
Primary liver cancer	5
Resection of centrally located liver lesion with primary tumor in place	8
Malignant	31
Benign (liver adenoma)	1
Neoadjuvant chemotherapy	13
Bilobar distribution lesion	7
Unilobar distribution lesion	24
Anatomic resection	15
Non-anatomical wedge resection	17
Wedge resection of segment IVa	10
Resection of lesion in SVIII	7
Anatomic resection	3
Wedge resection	4
Resection of lesions in SIVa	11
Anatomic resections	6
Wedge resections	5
Anatomical resection and concomitant non-anatomic resection of SI, IVb and VI	1
Lobar lesions resected via wedge resection in SIV and VIII	2
Wedge resection of lesion in SIV, V, VIII	1
Non-anatomic resection of lesion in VII and VIII	1
Formal mesohepatectomy leading to en bloc resection of SIV, V, VIII	6
Normal liver parenchyma	14
Cirrhosis	13
Steatosis	4
Mixed cirrhosis and steatosis	1
Average blood loss (29 reports)	403 cc (SD 475 cc)
Blood loss less than 200 cc	20
Blood loss of 1,000 cc or greater (max 1,500 cc)	6
3 mesohepatectomies	
1 wedge of SVIII	
1 segmentectomy of SVIII	
1 segmentectomy of SIVa	
Required blood transfusions (2–4 units)	4
Conversion during SIVa resection for HCC to open	1
Average hepatectomy operative time (29 reports)	183 min, (SD 136 min)
Average hepatectomy for mesohepatectomy	253 min (SD 94 min)
Average length of stay	10.4 days
Long stays	5
50 days	1 Multi-organ failure
49 days	1 Colonic leak
21 days	1 Bile leak
	1 Abscess at resection site
36 days	1 Pancreatitis with fistula
Histologically complete resection of index lesion	2 (R1 and R2)

All lesions except for one adenoma were malignant lesions, and the majority were colorectal liver metastases and HCC. Six patients underwent formal mesohepatectomy. Average blood loss was 400 cc, and the greatest amount of blood loss occurred in the mesohepatectomy cohort

ligaments for central liver resections remain intact to assist with retraction. Both portal pedicles are dissected out. The liver parenchyma is transected just to the right of the falciform ligament down to the IVC and then continue just to the left of the middle hepatic vein. The right liver is now retracted superiorly to visualize the borders of segments V, VI as well as VII, VIII, which should be demarcated at this point. All large branches between segments VII and VIII should be clipped or suture ligated. Special care must be taken not to injure the posterior sectoral branches of the bile duct. The transsection is continued until the right hepatic vein is encountered. Using the right hepatic vein as a landmark, the transsection is continued to the infradiaphragmatic inferior vena cava. This part requires utmost care as the drainage vein of segment VIII could be injured and result in difficult-to-control bleeding. In order to obtain outflow control, the middle hepatic vein should be stapled.

Results

Of the 32 evaluable patients, 13 were female, and 19 were male; all cases were performed laparoscopically as per the inclusion criteria (Table 1). The average age was 61 years [standard deviation (SD): 14.2; range: 28–87 years]. All patients had class I–III functional capacity according to the New York Heart Association functional classification system. Thirty-one patients had malignant lesions, and the remaining patient had a liver adenoma. Of the 32 patients, 17 underwent resection for colorectal liver metastasis, four for a neuroendocrine tumor, five for HCC, two for gastrointestinal stroma tumor (GIST), and one each for metastases from esophageal cancer, melanoma, and breast cancer. Of the resected lesions, 15 were metachronous metastases, 11 were synchronous metastases, and five were primary liver cancer. Eight patients had a resection of the centrally located liver lesion with the primary tumor in place. Of the 32 patients, 13 had undergone neoadjuvant chemotherapy. Seven lesions had a bilobar distribution, and the remaining had unilobar distribution.

Operations

Fifteen patients (47 %) underwent an anatomic resection, while 17 (53 %) underwent a non-anatomic wedge resection (Table 1). Ten patients had wedge resection of segment IVa, and seven patients had resection of a lesion in VIII. Of these resections in VIII, three were anatomic resections, and four were wedge resections. Of the resections in IVa, six were anatomic resections, and five were wedge resections. One patient had an anatomic resection of a lesion in IVa and concomitantly non-anatomic resection of I, IVb, and VI. One patient had a left hepatectomy and wedge resection of a lesion in V and VIII, another patient underwent anatomic resection of VII and a wedge of VIII, and a third patient had anatomic resection of VIII and wedge resection of V and VI. Two patients underwent wedge resection of bilobar lesions in IV and VIII. One patient had wedge resection of a lesion in IV, V, and VIII, and one patient had non-anatomic resection of a lesion in VII and VIII. Six patients underwent formal mesohepatectomy leading to an en bloc resection of IV, V, and VIII.

Intraoperative parameters

Average blood loss was 403 cc (SD 475 cc); twenty cases (63 %) had blood loss of less than 200 cc. Accurate information on blood loss was missing in three patients, although review of records did not indicate any complicating factors. (Table 1) Six cases with the greatest blood loss included three mesohepatectomies, one wedge resection of SVIII, one segmentectomy of SVIII, and one segmentectomy of SIVa. Four patients (12.5 %) required blood transfusions of 2–4 units. One patient underwent conversion to open surgery during a SIVa resection for HCC owing to injury to the portal vein that led to blood loss of 200 cc. The average hepatectomy operative time was 183 min (SD 106 min); data on the hepatectomy time was missing in three cases. The average hepatectomy time for the patients undergoing a complete mesohepatectomy was 253 min (SD 94).

Table 2 Complications

Dindo–Clavien grade I	3
Heparin-induced thrombocytopenia	1
Pleural effusions	2
Dindo–Clavien grade II	1
Fever of unknown origin until PO day 5	1
Dindo–Clavien grade IIIa	6
Bile leak	2
Bile leak with abscess	1
Abscess only	1
Pancreatitis associated with concomitant distal pancreatectomy	1
Pancreatitis with suprarenal LN biopsy requiring	1
Dindo–Clavien grade IIIb	1
Visceral artery bleed from splenic artery	1
Dindo–Clavien grade IV	1
Multi-organ failure due to small for size liver remnant	1

The majority of complications were Dindo–Clavien grade I or II or associated with the concomitant procedure (e.g., pancreatitis after pancreatectomy). The most significant complication was secondary to conversion of mesohepatectomy to extended right hepatectomy that led to postoperative liver insufficiency

Postoperative morbidity and mortality

There was no postoperative (30-day) mortality. Postoperative complications as graded according to the Dindo–Clavien classification included: grade I in three patients (9 %), grade II in one patient (3 %), grade IIIa in six patients (19 %), and grade IIIb and IV in one patient each (Table 2). The grade I complications were heparin-induced thrombocytopenia and two pleural effusions that did not require intervention. The grade II complication was fever of unknown origin for 5 days post-surgery prompting an ultrasound to rule out an abscess. The grade IIIa complications were two cases of bile leak with abscess formation. In addition, there were two abscesses associated with a pancreatic leak. There were also two cases of pancreatitis associated with a concomitant distal pancreatectomy, and a suprarenal lymph node biopsy associated with extensive pancreatic mobilization. The IIIb complication was splenic artery bleed requiring reoperation. The grade IV complication was a patient with multi-organ failure due to small size future liver remnant. This patient required conversion from a planned mesohepatectomy to a completion extended right hepatectomy at the completion of the case due to devascularization of the posterior segments and a second lesion in SVI that could not be removed even after the mesohepatectomy had been completed. In summary, mortality, transfusion, and morbidity rates were 0, 12, and 37 %, respectively, of which 12 % were Dindo–Clavien grade I or II only.

The average length of hospitalization was 10.4 days (range: 3–50 days). Five patients had longer than 21 days of hospitalizations for pancreatitis with fistula during concomitant distal pancreatectomy (36 days), bile leak (21 days), abscess at the resection site (21 days), multi-organ failure due to small size future liver remnant (50 days), and colonic leak complication of an associated low anterior resection (49 days).

Histologic analysis confirmed normal liver parenchyma in 14 patients, some degree of cirrhosis in 13 patients (mild in most cases), steatosis in four patients, both cirrhosis and steatosis in one patient, and no reported underlying liver parenchymal damage in one patient.

Oncologic data

Histologic complete resection of the index lesion was achieved in all but two cases, which had R1 and R2 resections, respectively.

Follow-up oncologic data were obtained for patients with malignant disease who underwent surgery before May 2011 to allow at least 1 year of follow-up. Of the 20 patients with malignant disease and intermediate-term follow-up, six had tumor recurrence, 14 had no recurrence within the study period; one patient had an adenoma and did not have long-term follow-up. All recurrences fell within the average disease-free interval published by the Surveillance epidemiology and end results program (http://seer.cancer.gov/statfacts) for the respective disease entity. One patient was found to have systemic recurrence with pulmonary and osseous metastases 8 months after hepatectomy.

Discussion

Surgical management of lesions located in the central segments is considered challenging even when an open approach is used [5]. Our findings indicate that laparoscopic liver resection of the central segments, as well as complete mesohepatectomy (video) is a feasible, safe, and effective alternative to open surgery. Current laparoscopic liver resection literature is dominated by non-anatomic resection of accessible segments and no other laparoscopic central hepatectomy series exists. Thus, we present our results in the context of the open central hepatectomy literature. Despite a better understanding of liver anatomy and technological advances in laparoscopic liver surgery, major laparoscopic liver resection remains challenging and is performed in only a few centers worldwide. Liver resections for those lesions in the posterior superior central segments are considered the most challenging to perform laparoscopically and even more difficult using a parenchymal-sparing approach. Nevertheless, our study reported mortality, transfusion, and morbidity rates were 0, 12, and 37 %, respectively, of which 12 % were Dindo–Clavien grade I or II only. These parameters are comparable to those reported for open surgery: Chouillard et al., reported mortality, transfusion, and morbidity rates of 0, 26, and 19 %, respectively, for open central liver resection [5]. Other groups from experienced centers have reported similar results for open parenchymal-sparing resection of lesions in the central segments [6]. In our series, the most severe complications (i.e., grade IIIb and IV) were secondary not to the liver resection but to concomitant procedures. These complications include pancreatitis, pancreatic fistula, and colonic anastomotic dehiscence. We do not think it can be concluded that the complications of the secondary procedure are related to the fact that the laparoscopic liver resection of the centrally located lesion was performed during the same operation. Studies of open liver surgery from both Asian and Western institutions have shown that concomitant colon or pancreatic surgery is safely practiced in experienced centers [16, 17]. In our experience, both open and laparoscopic liver surgery in patients with a borderline liver reserve, concomitant secondary procedures should be avoided although this is a valuable conclusion, it is not specific to a laparoscopic approach.

Among the patients in this study, six patients underwent formal laparoscopic mesohepatectomy, the largest such cohort reported to date. We have included an accompanying video in the supplemental section in which indocyanine green counterstaining was used to delineate the central liver. What remains unknown is whether a parenchymal-sparing technique for either an open or minimal access approach affects intra- and postoperative parameters and overall outcomes. Three retrospective studies addressing this question found no differences between mesohepatectomy and extended hepatectomy with regard to perioperative morbidity and mortality rates or the mean length of postoperative hospital stay [9, 18, 19]. This finding suggests mesohepatectomy should be considered mainly for patients who have borderline liver function and who would otherwise not be candidates for resection if a parenchymal-sparing technique was not employed.

The duration of hospitalization for our patients might appear lengthy to North American readers and prompt the question of whether the short-term benefits of laparoscopic surgery in the immediate postoperative period were preserved in our cohort. Published data on the differences in health care delivery between European countries and the

United States reveal a generally longer duration of hospitalization for European patients. The lengthy hospitalization in our cohort may be explained by the fact that patients at our institution are discharged only after they have been rehabilitated as inpatients to a level where they can function completely independently in their home environment.

A limitation of our study is the lack of conclusive oncologic data from our heterogeneous cohort aside from completeness of resection and survival rates for the respective disease entity that fall within the published data [20]. Although our data did not include numerical values of surgical margins, a parenchymal-sparing approach, by definition, yields smaller margins than non-parenchymal-sparing approaches such as extended hepatectomies. Whether anatomic resection according to Couinaud's classification has a survival benefit over non-anatomic resection is controversial. A series from an Asian center demonstrated that survival was significantly better in the group that underwent resection according to Couinaud's classification than in the group that underwent non-anatomic resection [21]. Using a nationwide Japanese database of 72,744 patients, another group compared the outcomes of anatomic and non-anatomic resection for HCC and reported longer durations of disease-free survival with anatomic resection but no difference in overall survival. When survival was stratified by tumor size, disease-free survival was significantly longer with anatomic resection for HCC with a diameter of 2–5 cm [22]. This study contradicted findings of Western studies in which only tumor size and vascular invasion affected survival [23]. The issue of oncologic outcomes of patients undergoing laparoscopic liver surgery was recently addressed in a comprehensive meta-analysis. The hazard ratio (HR) of malignant tumor recurrence was no different between the open and laparoscopic groups (HR 0.79; $P = 0.37$), and the mortality rate in patients with malignant tumors was significantly lower in the laparoscopic group (HR 0.64; $P = 0.04$). Whether the positive results from this meta-analysis and other studies can be applied to patients with centrally located lesions needs to be determined as most published articles on laparoscopic liver resections are dominated by wedge resections [4].

Data regarding the skills and concepts a liver surgeon should have mastered prior to attempting laparoscopic liver resection are limited and do not specifically address lesions in the central segments. These skills include laparoscopic liver mobilization, inflow control and occlusion, safe use of staplers and salvage techniques of stapler misfiring, parenchymal transsection, identification of the transsection plane, various techniques for controlling parenchymal and vascular bleeding, and staged conversion [1]. Critical for performing anatomic liver resection, and more specifically laparoscopic mesohepatectomy, is the use of laparoscopic ultrasound and a thorough understanding of liver anatomy with its anatomic variants (Figs. 1, 2).

In conclusion, we present the first series of laparoscopic resection of centrally located liver lesions and the first series of mesohepatectomy. In this series, we report favorable short- and intermediate-term outcomes compared to an open approach. As laparoscopic liver surgery is practiced more widely and more complex laparoscopic liver resections are performed, we believe it will be essential for centers that perform these surgeries to confirm the oncologic outcomes through multi-institutional studies, long-term follow-up, and standardization of technique.

Disclosures Drs. Claudius Conrad, Satoshi Ogiso, Yosuke Inoue, Nairuthya Shivathirthan, Brice Gayet reports no financial interests or potential conflicts of interest.

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