Pure laparoscopic formal right hepatectomy versus anatomical posterosuperior segmental resections: a comparative study

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Background: To analyze the differences in perioperative outcomes between laparoscopic formal right hepatectomies (RH) and laparoscopic anatomical posterosuperior (PS) resections, including segmentectomies in PS segment SVII and right posterior sectionectomies (segment VI and VII resection).

Methods: A retrospective analysis of all patients undergoing laparoscopic formal RHs and anatomical PS resections, including segmentectomies in PS segment SVII and right posterior sectionectomies (segment VI and VII resection), between January 2010 and August 2017 was performed. The two groups were compared in terms of patients' characteristics, intraoperative parameters, and short-term outcomes.

Results: Sixty-eight patients were included of which 32 RHs and 36 anatomical PS resections. In the PS resection group, 18 had a segmentectomy of segment VII and 18 had a bisegmentectomy of both segments VI and VII. Patients' preoperative data were comparable. The lesion size was higher in the RHs (P<0.001). A significant shorter operative time was found in the PS group: 280 [230–315] *vs.* 357 [300–463] min in the RH group (P<0.001). Blood loss was comparable: 520 [390–906] in the RHs *vs.* 560 [370–1,030] in the PS group (P=0.595). The overall morbidity rate was comparable being 25% in the RHs and 22.2% in the PS group (P=1.000). A longer length of stay (LOS) {7 [5–8] *vs.* 5 [4–7] days, P=0.012} and higher readmission rate (12.5% *vs.* 0%, P=0.044) was observed in the RHs compared to the PS cohort. Concerning surgical margins, the R0 rate was comparable in the two groups; 90.9% in the RHs *vs.* 95.2% in the PS group (P=1.000).

Conclusions: When deemed feasible based on lesion position and size, the laparoscopic parenchyma-preserving approach using anatomical PS segmental resections is associated with shorter hospital stay and a lower readmission rate in respect to formal RH. Overall, short-term surgical parameters indicated that both procedures are safe and feasible in experienced hands, however both demand a great deal of technical expertise.

Keywords: Laparoscopic liver resection; postero-superior segments; right hepatectomy (RH)

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Introduction

Despite the initially slow and tentative dissemination of minimally invasive procedures in liver surgery, the number of laparoscopic hepatectomies has increased in an exponential manner over the last years (1). Better outcomes compared to the standard approach have been widely reported, including a lower morbidity rate, decreased blood loss and a shorter length of stay (LOS). Other advantages are reduced tissue inflammation and surgical trauma, resulting in less anatomical changes such as adhesions and possible postoperative liver decompensation (2).

As suggested during the International Consensus Conferences on Laparoscopic Liver Surgery in Louisville and Morioka and furthermore in the latest *European Guidelines on Laparoscopic Liver Surgery*, the laparoscopic approach is nowadays considered as the gold standard for minor resections such as left lateral sectionectomies and resections for lesions located in the anterolateral segments (3-5).

Conversely, laparoscopic major resections and resections of lesions located in the posterosuperior (PS) segments (IVa, VII and VIII) are still considered technically challenging and reserved for experienced surgeons in specialized centers. Experts thereby highlight that resections in these difficult segments, especially when anatomical, are technically far more difficult to perform than laparoscopic major resections, subsequently assigning these resections (i.e. PS resection) the highest score in recent difficulty scoring systems (5-8).

Encountered issues in these procedures are mainly the limited working space, the curvilinear resection plane, the difficult exposure of the liver parenchyma close to the diaphragm, the difficult evaluation of the resection margin by ultrasonography (US) and the increased risk of uncontrollable bleeding (9,10). All of these above-mentioned limitations are moreover enhanced in case of anatomical resections because of the wider transection surface, the difficulty in evaluating the anatomical borders, the deeper resection plane and even more limited exposure. Therefore, the open approach remains the gold standard for PS lesions in many hepatobiliary centers. Regardless, several recent reports described fewer postoperative complications and comparable oncologic outcomes in laparoscopy compared with the open approach (11-13).

Besides, some authors even recommend a laparoscopic formal right hepatectomies (RH) for PS-sided lesions rather than a parenchyma-preserving procedure, as reduced parenchyma removal in that areas might be laparoscopically more complex (5,14,15). Despite this, the preservation of functional parenchyma is surely valuable due to the diminished risks of post-hepatectomy liver failure (PHLF) in case of altered liver background, and because of the possibility of a repeated resection (totalization of an RH) in case of recurrence, possibly improving long-term outcomes (16-19).

To the best of our knowledge, few reports have previously been published analyzing the outcomes of laparoscopic formal RH compared to PS resections, of which none focused on anatomical resections (20,21). Therefore, the aim of this study was to analyze the differences in perioperative outcomes between these procedures.

Methods

After approval of the local Independent Ethics Committee, a retrospective analysis of all patients undergoing laparoscopic formal RH and anatomical laparoscopic PS resections, including segmentectomies in PS segment SVII and right posterior sectionectomies (segment VI and VII resection), between January 2010 and August 2017 was performed. Liver resections were defined according to the Brisbane 2000 terminology (22). Anatomical resections in segment VII as well as posterior sectionectomies were selected as these resections are technically more demanding than wedge resections; this is due to the wider transection surface, a deeper resection plane with exposure of the major hepatic veins and respective portal pedicles, requiring advanced skills in hepatobiliary laparoscopic surgery (23).

Anatomical resection of segments VI–VII was defined as dissection of the portal pedicles in the De Rouvière sulcus, by partially exposing the inferior vena cava (IVC) and skeletonizing the lateral side of the right hepatic vein (RHV) until its confluence to the IVC. Segmentectomy of segment VII was defined by exposing the RHV medially, the IVC following partial mobilization and closure of some accessory veins, the RHV joining the IVC and the portal pedicle 7.

Patients were older than 18 years, had no significant extrahepatic disease and sufficient future liver remnant. Patients undergoing concomitant extrahepatic resections or microwave ablation, concomitant wedge resections in other liver segments, extended right hepatectomies and non-anatomical resections were not selected for our study. The indication for surgery and its approach were discussed in a multidisciplinary meeting of surgeons, gastroenterologists, oncologists, radiologists and pathologists.

The primary outcome of the study was the postoperative morbidity, defined as the complications occurring at any time during the post-operative hospital stay or within 3 months after surgery. Complications were classified according to Clavien-Dindo's classification and categorized as minor (grade < III) and major (grade ≥ III) (24). If a patient experienced more than one complication, the most severe one was taken in account for the Clavien-Dindo classification. The Comprehensive Complication Index (CCI) was used to describe overall morbidity (25). Readmission within 3 months from discharge was considered. Secondary outcomes were blood loss, operative time, conversion rate, LOS and histological characteristics. Blood loss was evaluated by taking into account the subsequent fall in plasma hemoglobin levels and the gauze weight in the operation room. R1 margins (a margin width less than 1 mm at microscopic evaluation) were distinguished as standard parenchymal R1 and vascular R1. The latter resulting from the detachment of tumor from major hepatic vessels (26,27).

Statistical analysis

Test for normality using Shapiro-Wilks was performed for each continuous variable; no variables were parametric. Continuous non-parametric data are reported as median and interquartile range and compared using the Mann-Whitney test. Categorical variables were expressed as numbers and percentages and compared using the Chi-squared or Fisher's exact test when appropriate. All analyses were executed by SPSS Statistics 25.0. The level of statistical significance was set at P less than 0.05.

Results

A total of 68 patients was enrolled of which 32 were formal RH and 36 anatomical PS resections. The PS group consisted of 18 segmentectomies of segment VII and 18 posterior sectionectomies of both segments VI and VII. A subgroup analysis between these latter two groups (segmentectomies of segment VII and posterior sectionectomies) did not reveal any differences in perioperative data and short-term postoperative outcomes. Other PS resections such as segmentectomies of segment VIII or IVa or bisegmentectomies of S VII and S VIII or S VIII and S IVa were omitted as the number of cases with true anatomical resections was too low to draw any conclusions.

Patients' demographics are displayed in *Table 1*. No significant difference in terms of age, gender, comorbidity, ASA classification, previous abdominal surgery, indication for surgery and number of lesions was found. The lesion size was distinct in the two groups, being higher in the right hepatectomies (P<0.001), yet the number of lesions did not differ significantly (P=0.095).

A significant shorter operative time was found in the PS group in respect to RH group (P<0.001). Blood loss and conversion rate were not significantly different, (P=0.595 and P=0.135) (*Table 2*). Reasons for conversion in the RHs were laborious progression due to tight adhesions [2], hypertrophy of the lobus caudatus [1], oncological concerns [1], bleeding of a portal branch after stapler failure [1], tear of the right diaphragm while removing the right liver, causing hemorrhagic shock [1]. In the PS group, 2 patients needed conversion: one patient because of frozen abdomen (segmentectomy VII) and one patient because of hemorrhagic shock and fulminant respiratory failure (posterior sectionectomy).

The overall complication rate was comparable in the two groups (P=1.000). There were no differences according to the Clavien-Dindo Classification (P=0.917). The CCI calculation did not reveal significant difference (P=0.645) (*Table 2*). The specific postoperative complications are displayed in *Table 3*. Some correlations were noted: (I) the patient who needed conversion due to bleeding of a portal branch after stapler failure developed postoperative pleural effusion and ascites which was treated conservatively; (II) a postoperative thorax drainage due to pneumothorax was required in the patient who had conversion due to a tear in his right diaphragm and hemorrhagic shock; (III) pleural effusion, treated conservatively, was diagnosed in the patient who had conversion due to frozen abdomen; (IV) postoperative intensive care stay was obligated due to acute respiratory distress syndrome (ARDS) in the patient having conversion due to hemorrhagic shock and fulminant respiratory failure; (V) acute renal failure in a patient with previous cardiovascular insufficiency; (VI) respiratory failure and death in one 81-year-old female with a noticeable surgical history; (VII) one bile leak which might be related to sparing of the middle hepatic vein; (VIII) one pneumothorax which might be related to the use of an intercostal trocar, yet no clear correlation can be found as only 1 out of the 4 patients treated with an intercostal trocar had a remarkable pneumothorax. No fulminant liver impairment was noted, although in a limited number of patients, cirrhosis was diagnosed on anatomopathological examination, 1 (3.1%) in the RHs and 5 (13.9%) cases in the PS group.

Table 1 Patients' demographics

Demographics	Laparoscopic formal right hepatectomies (n=32)	Laparoscopic anatomical posterosuperior resections (n=36)	P value
Age (yr), med (IQR)	54 (43–68)	56 (40–69)	0.951
Male gender, n (%)	11 (34.4)	12 (33.3)	0.928
BMI (kg/m^2), med (range)	27 (22.1–28.9)	25 (22.1–30.1)	0.676
Comorbidities, n (%)	13 (40.6)	16 (44.4)	0.809
Previous abdominal surgery, n (%)	10 (31.3)	6 (16.7)	0.252
ASA grade, n (%)			0.279
1	12 (37.5)	7 (19.4)	
2	15 (46.9)	22 (61.1)	
3	5 (15.6)	7 (19.4)	
Malignant lesions, n (%)	22 (68.8)	21 (58.3)	1
Malignant indications, n (%)			1
CRLM	12 (54.5)	13 (61.9)	
NCRLM	3 (13.6)	3 (14.3)	
HCC	4 (18.2)	3 (14.3)	
CCC	3 (13.6)	2 (9.5)	
Benign indications, n (%)			0.926
Adenoma	7 (70.0)	10 (66.7)	
Hemangioma	2 (20.0)	3 (20.0)	
Liver cyst	1 (10.0)	1 (6.7)	
FNH	0 (0.0)	1 (6.7)	

BMI, body mass index; ASA, American Society of Anesthesiology; CRLM, colorectal liver metastases; NCRLM, non-colorectal liver metastases; HCC, hepatocellular carcinoma; CCC, cholangiocarcinoma; FNH, focal nodular hyperplasia.

The LOS was significantly longer in the RHs {7 [5–8] days} *vs.* the PS resections {5 [4–7] days} (P=0.012). In non-converted cases, the LOS for RHs was 6 [5–8] days *vs.* 5 [4–6.5] days for PS (P=0.054). Readmission within 3 months post-operatively was registered in 4 (12.5%) patients undergoing an RH and in none of the PS group patients (P=0.044). The reasons for readmission in the RH group were: bilioma [1], subdiaphragmatic infected collection [1], general deterioration and anorexia [1], fever, pleural effusion and ascites [1].

From the oncological point of view, the R0 rate was 90.9% in the RHs and 95.2% in the PS group. Two positive R1 (vascular) margins were induced by sparing the origin of the RHV in a posterior sectionectomy and sparing the middle hepatic vein in a right hepatectomy. Despite meticulous follow-up of the oncological patients, the relatively small number of patients with colorectal liver metastases (CRLM), did not allow us to draw any meaningful conclusion in terms of oncological recurrence.

Discussion

The evolution of technology and experience in laparoscopic liver surgery have recently broadened the surgical indications enabling major RH as well as resections of lesions located in the PS segments of the liver, previously considered non-laparoscopic segments. Laparoscopic liver resections in fact, showed similar results compared to the standard approach in terms of perioperative morbidity and long-term outcomes, being associated with advantages as

Table 2 Patients' perioperative data

Perioperative data	Laparoscopic formal right hepatectomies (n=32)	Laparoscopic anatomical posterosuperior resections (n=36)	P value
No. of lesions, n (%)			0.095
1	20 (62.5)	23 (63.9)	
2	4 (12.5)	10 (27.8)	
≥3	8 (25.0)	3 (8.3)	
Largest lesion size (cm), med [range]	8.5 [7.5–13]	5 [4.5–6.4]	<0.001
Cirrhosis, n (%)	1 (3.1)	5 (13.9)	0.203
Operative time (min), med [range]	357 [300–463]	280 [230–315]	<0.001
Blood loss (mL), med [range]	520 [390–906]	560 [370–1,030]	0.595
Vascular clamping, n (%)	9 (28.1)	14 (38.9)	0.444
Pringle time (min), med [range]	18 [10–31.5]	30 [18–45.5]	0.21
Conversion, n (%)	6 (18.8)	2 (5.6)	0.135
Margin status*, n (%)			1.000
R0	20 (90.9)	20 (95.2)	
R1	1 (4.5)	0 (0.0)	
R1 vascular	1 (4.5)	1 (4.8)	
Mortality, n (%)	0	1 (2.8)	1.000
Overall complications, n (%)	8 (25.0)	8 (22.2)	1.000
Clavien-Dindo classification, n (%)			0.917
Minor morbidity (<III)	3 (9.4)	4 (11.1)	
Major morbidity (≥III)	5 (15.6)	4 (11.1)	
CCI, med [range]	26 [20.9–40.5]	24 [12.5–38.4]	0.645
Hospital Stay (days), med [range]	7 [5–8]	5 [4–7]	0.012
Readmission, n (%)	4 (12.5)	0 (0.0)	0.044

*, concerning 43 patients operated for malignancy. CCI, comprehensive complication index.

diminished blood loss and a shorter LOS (19,28).

While it has been shown that limited non-anatomical resections in the PS segments preserve functional parenchyma compared to the formal RH and are associated with better short-term outcomes compared to the open technique, the advantages and disadvantages of anatomical resections located in the PS segments are not well-known.

Considering our two groups of patients, short-term surgical parameters showed that both procedures are safe and feasible in experienced centers. Blood loss was low and comparable between the two groups. Both RH and PS resection have different factors related to the intraoperative bleeding. For the RH, the extensive mobilization and the large amount of liver parenchyma is responsible for intraoperative bleeding, even with the usually performed right inflow occlusion. For the PS, their difficult location and the challenges in managing uncontrollable bleeding are the factors influencing blood loss. We believe that meticulous Cavitron Ultrasonic Surgical Aspirator (CUSA) dissection, Pringle maneuver, low central vein pressure together with the buffer effect of the pneumoperitoneum and the magnification of view are the main determinants for decreasing the blood loss in laparoscopic liver resections, especially in difficult cases. Furthermore, experience in

Table 3 Postoperative complications according to Clavien-Dindo's Classification

	Laparoscopic formal right hepatectomies (n=32)	Laparoscopic anatomical posterosuperior resections (n=36)
I	Wound hematoma, n=1	Pleural effusion, n=1
		Pneumothorax, n=1
II	Pneumonia, n=1	Pneumonia, n=2
	Pleural effusion and ascites, n=1	
IIIa	Subdiaphragmatic collection, n=1	Pneumothorax, n=2
	Bile leak, n=1	
	Pneumothorax, n=1	
IVa	ARDS, n =1	ARDS, n=1
	Acute renal failure, n=1	
V		Respiratory failure, n=1

ARDS, acute respiratory distress syndrome.

hepatobiliary surgery and complex laparoscopy, as well as a stepwise learning curve are necessary to achieve a standardization of the technique: both RH and PS resection are in fact the procedures that should be approached laparoscopically in a late stage of the learning curve. One might start resecting small lesions located in the anterolateral segments gradually shifting to more complex procedures, in order to finally reduce unexpected intraoperative events or to know how to manage it—bleeding in most of the cases—without putting the patient at risk for a rapid conversion (29).

Although the conversion rate did not differ statistically, a higher rate was observed in the RHs. Indeed, major hepatectomies, especially when right-sided are challenging and associated with different pitfalls during pedicle dissection, parenchymal transection, mobilization and hepatocaval confluence dissection (30,31). The longer operative time registered in the RH group is presumably due to the approach to the hilum and the hanging of the right lobe which is particularly difficult especially in case of large lobes. In fact, more vascular and biliary structures have to be selectively clipped and cut during an RH. Furthermore, the hepatic pedicle dissection, the hepatic vein stapling and the right liver mobilization also contribute in increasing the operative time.

PS group was associated with a reduced LOS probably related to the less amount of parenchyma resected and the minor complications. It is reasonable in fact that biochemical changes and drain output in the postoperative period were more evident in the RH group possibly delaying patient's discharge.

Postoperative morbidity was comparable in the two groups, yet there was a higher readmission rate in the RH cohort. Noteworthy, this might endorse the notion that preservation of liver parenchyma decreases the risk of postoperative liver failure and is therefore a positive predictor for decreased morbidity and mortality especially in the setting of liver cirrhosis and chemotherapy (32). Recently, a French group demonstrated that patients undergoing a laparoscopic resection in PS segment VII and/or VIII significantly developed less complications than patients undergoing a formal RH. Nevertheless, only 33.3% of the patients in their PS group had an anatomical resection while our PS group consisted of anatomical resections only (21). Further studies also suggested that right posterior sectionectomies are similar to formal RHs in terms of morbidity and that laparoscopic major hepatectomies (right and left hemihepatectomies and trisegmentectomies) and PS segments resections (IVa, VII, VIII) have no difference in terms of complication rate, yet none of these studies focused on formal RHs and anatomical PS resections only (20). Thus, if preserving liver parenchyma is associated with better outcomes, one should perform non-anatomical minimal resections rather than anatomical resections, yet in terms of lesion size and lesion position anatomical resections might be imposed.

In recent years, the better knowledge of the hepatic anatomy and the use of intraoperative ultrasound ushered in an age of increased laparoscopic parenchyma-preserving liver resections. This worldwide trend in hepatobiliary centers was favored by plenty of evidence supporting that the width of the negative resection margin in CRLM did not affect recurrence risk or survival (33). Parenchyma-preserving liver resections avoiding the unnecessary sacrifice of functional parenchyma, are thus an alternative approach to extensive liver resections in selected patients, possibly allowing re-resection in case of recurrence. As tumor relapse is seen in at least two-thirds of patients with CRLM, the potential of repeat hepatectomy stresses the utmost importance of parenchymal preservation in the initial operation (10).

This study has some limitations. In fact, its retrospective design does present some bias. Furthermore, the small number of enrolled patients as a result of clear selection of patients in a single-center analysis does not allow interpolation of results. Concerning our PS group, only resections of segment VII and right posterior sectionectomies were included. Further studies are needed to focus on the results of anatomical laparoscopic resections of segments VIII and IVa, which are difficult to approach due to its position at the very top of the liver dome, close to the RHV. Also, the relatively small number of patients with CRLM did not allow us to draw any meaningful conclusion in terms of oncological repercussions. The preoperative 3D reconstruction of the hepatic anatomy, the meticulous intraoperative US guidance and the use of intraoperative negative or positive fluorescence staining are tools that could help obtaining a precise anatomical resection aiming to improve the R0 margin rates (34).

The patient population was heterogeneous, mainly based on the differences in tumor size, not allowing us to indicate whether or not patients undergoing a formal RH would have been suitable candidates for a parenchymal-preserving resection. A large-scale study is needed to confirm our results and to focus on long-term outcomes as well as oncological differences in a more homogenous population matched for tumor size and location.

Conclusions

When deemed feasible based on lesion position and size, the laparoscopic parenchyma-preserving approach using anatomical PS segmental resections is associated with shorter hospital stay and a lower readmission rate in respect to formal RH. Overall, short-term surgical parameters indicated that both procedures are safe and feasible in experienced hands, however both demand a great deal of technical expertise.

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None.

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was approved by institutional ethics board of Universitair Ziekenhuis Gent (NO.: B670201629283).

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