Segment 5 parenchymal sparing in extended left hepatectomy with respect to venous outflow—is it a feasible procedure

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HOW-I-DO-IT ARTICLE

Segment 5 parenchymal sparing in extended left hepatectomy with respect to venous outflow—is it a feasible procedure?

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Abstract

Background Segment 5 (S5) sparing liver resection for cases that require an anatomic left trisectionectomy has not been reported yet. The authors intended to verify the outcome of S5-sparing extended left hepatectomy (ELH) in respect to venous outflow.
Methods All adult patients who underwent S5-sparing ELH between 2012 and 2017 in authors' institute have been enrolled in this study. S5-sparring ELH was defined as resection of S2, S3, S4, and S8 with or without S1. The surgery planning was based on the images from two-dimensional triphasic computed tomography and/or magnetic resonance imaging. A three-dimensional image reconstruction and liver volumetric study were performed retrospectively.
Results Out of 177 cases of major hepatic resection, only seven non-hilar cholangiocarcinoma patients underwent ELH during the study period. S5-sparing ELH was performed to five patients, in whom no tumor involvement in S5. The venous outflow of S5 has been maintained intraoperative, and S5 congestion has not been observed in all patients. Tailored management of the S5 venous outflow ensured an increase in functional remnant liver volume by 52.8% (range, 25.6 to 66.9%) by sparing of S5. A negative resection margin was achieved in all patients. One patient had postoperative bile leak requiring reoperation. No posthepatectomy liver failure (PHLF) has been observed.
Conclusion S5-sparing ELH is technically feasible. Under the tailored management of S5 venous outflow, the functional future liver remnant can be increased. Further studies with larger sample size are needed to evaluate which circumstances the liver segment 5 could be preserved without venous reconstruction during the left extended hepatectomy.

Keywords Hepatectomy · Liver failure · Liver volume · Outflow

Introduction

Major hepatectomy in oncologic liver diseases has always been a challenging topic for hepatobiliary surgeons. The target of liver resection (LR) is not only to achieve a negative resection margin (R0) but also to preserve an adequate remnant liver volume to avoid posthepatectomy liver failure (PHLF) which is the main cause of death after major hepatectomy [1, 2].

Part of the results from this manuscript was selected and presented at the 131st Congress of German Surgical Society in Berlin, March 2014 as well as at the IHPBA World Congress 2014 in Seoul.

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Left trisectorectomy is one of the most extensive anatomic liver resection. The surgical technique of left trisectionectomy (resection of liver segments 2, 3, 4, 5, 8) was first described in 1982 by Starzl and colleagues [3]. High morbidity and certain mortality have been reported after left trisectionectomy due to the inadequate residual liver volume and the demanding surgical technique. PHLF was the most common complication after the extensive parenchymal loss [4–6]. Hence comes the need to report parenchymal sparring LR for liver diseases that are potentially undergoing anatomic left trisectionectomy.

The benefits of parenchymal sparring in liver resection are to avoid PHLF and to enable further LR in case of new lesions developed in the remnant liver parenchyma in the future. In patients with tumor extension from the left hemi-liver to segment 8 (S8) but not S5, left trisectionectomy has been widely performed in order to remove the involved segment with the tumor and to resect S5 which might develop parenchymal congestion due to detached S5 venous tributaries. The importance of hepatic venous outflow has been widely studied

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within the context of living donor liver transplantation [7, 8]. However, data in the context of oncological surgery are scarce [9].

The authors intended to verify the outcome of S5-sparing extended left hepatectomy (ELH), which was performed in selected cases for non-hilar cholangiocarcinoma patients, in respect to venous outflow.

Patients and methods

All adult patients who underwent S5-sparing ELH due to suspected liver malignancy between 2012 and 2016 in authors' institute have been enrolled in this study. S5-sparring ELH was defined as resection of S2, S3, S4, and S8 with or without S1. The S5 preservation was performed under three circumstances: (1) when there was no pre- or intraoperative evidence of S5 involved by the tumor, (2) when at least 1 cm of safety resection margin from the tumor could be ensured, and (3) when no significant S5 congestion was observed intraoperative. The caudate lobectomy was carried out en bloc with ELH when there was tumor involvement in S1. S5-sparing ELH has not been performed to patients with hilar cholangiocarcinoma as S5-sparring does not fit the oncological concept for this population.

The surgical planning was based on the preoperative images from two-dimensional computed tomography (CT) and/or magnetic resonance imaging (MRI). After exploration and liver mobilization, intraoperative ultrasound examination (IOUS) was carried out to localize the tumor as well as the main trunk of the middle hepatic vein (MHV), the right hepatic vein (RHV), and the right portal pedicle. The projections of these three structures on the liver surface were marked with electric cautery. The left portal vein and left hepatic artery were transected at the liver hilum. Thus, the boundary of S5 became obvious. The parenchymal transection was carried out by using cavitron ultrasonic surgical aspirator (CUSA). After dividing the S4b from S5, the S8 portal pedicle was exposed and transected. The further parenchyma transection followed the demarcation line or at 1 cm from the lateral tumor boundary if the demarcation of S8 was not obvious due to the large tumor mass. The RHV was repeatedly controlled by the IOUS to avoid injury. Intermittent Pringle maneuver was applied to maintain hemostasis when liver parenchymal was found to be fragile and excessive bleeding was expected.

The algorithmic approach for the intraoperative management of S5 outflow was kept as one of the following two scenarios (see Fig. 1):

1) MHV was not invaded by the tumor at the preoperative CT or MRI and IOUS ➔ Resection of the venous tributary of S8 (V8) with preserving the main trunk of the MHV was performed.
2) The MHV was involved within the tumor at the preoperative CT or MRI and IOUS →The MHV was resected together with V8:

    i) No large venous tributary of S5 (V5) was encountered during the parenchyma transection. No congestion was found at S5. In this situation, the venous outflow of S5 was supposed to be completely drained by RHV as an anatomical variation.
    ii) Large V5 was isolated and secured with a vascular clamp during the parenchyma transection. Venous reconstruction was also not carried out when S5 appeared slightly dusky but without stiffness. In this situation, there could be communicating veins between the MHV and the RHV.
    iii) In case of severe S5 congestion, a venous reconstruction would have been performed to maintain S5 venous outflow to inferior vena cava (IVC).

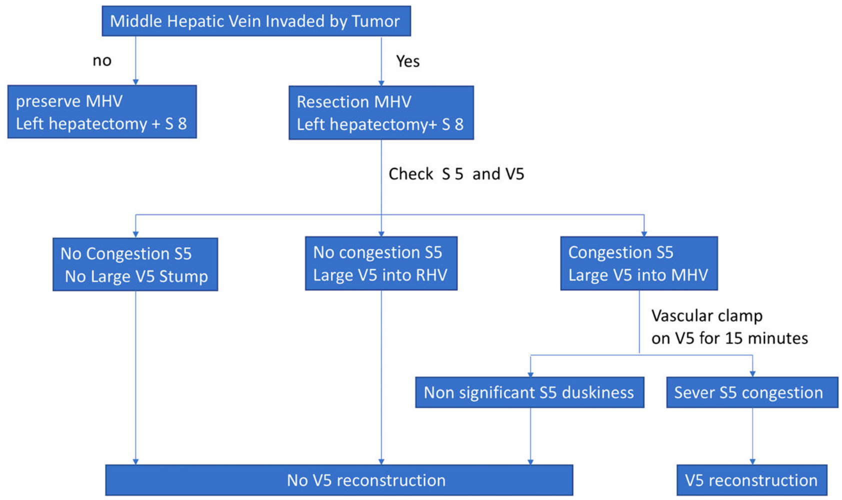
A three-dimensional (3D) image reconstructed from computed tomography was carried out retrospectively to demonstrate the venous drainage of S5 and to calculate the ratio of liver volume of the posterior section (S6 and S7) to the total liver volume (TLV) and to body weight either with or without S5. Data of the patients were analyzed retrospectively with regard to patients' characteristics: operative details such as extension of liver resection, vascular occlusion, requirement of blood products, postoperative complications according to Dindo-Clavien classification [10] with specific to PHLF, bile leakage, posthepatectomy hemorrhage (PHH) according to ISGLS classification [11, 12] and pathologic findings, as well as outcome measured by disease-free survival and overall survival. Clinical follow-up for all patients was obtained until December 2017.

Results

Among 177 major liver resections during the study phase, ELH was found in seven non-hilar cholangiocarcinoma patients. In two patients, the tumor involved not only the left hemi-liver but also the S5 and S8, so that anatomic left trisectionectomy was inevitable. S5-sparing ELH could be carried out in the other five patients, in whom no tumor involvement of S5 was found. Four patients were preoperatively diagnosed with intrahepatic cholangiocarcinoma (IHCCA), and one patient was diagnosed with hepatocellular carcinoma (HCC) (Table 1).

As evidenced by preoperative two-dimensional CT scans or MRI and IOUS, the main trunk of the MHV was infiltrated by the tumor in three patients while in the other two patients, the MHV was intact.

Fig. 1 The algorithmic approach for the intraoperative management of segment 5 outflow



- In the two patients where MHV was not invaded by the tumor, left hepatectomy along with S8 and its venous branches (V8) was performed. The main trunk of the MHV was preserved and the venous outflow of S5 remained intact though the MHV (Fig. 2).
- In the three patients where the MHV was invaded by the tumor, the venous outflow of S5 was through the RHV in two patients. Thus, the resection of MHV did not interfere with S5 venous outflow (Fig. 3).
- In the 5th patient, S5 was draining in the occluded MHV. MHV was resected while V5 was secured by a vascular clamp with an intention to perform vascular reconstruction in case of severe congestion. After 15 min of observation, no significant duskiness or congestion was seen in S5. Thus, no reconstruction of the prepared S5 venous tributary was carried out (Fig. 4a, b).

The analysis of the liver volume showed that by preserving the S5, the FLR was increased by 52.8% (range, 25.6 to 66.9%) and so the percentage of liver volume, represented by FLR/TLV, range from 20.5 to 43.6% without S5 to 31.3 to 64.9% with S5. FLR/BW ratios were ranging from 0.72 to 1.33% (Table 2).

Of these five S5-sparing ELHs, concomitant formal S1 resection was performed in four patients. One patient underwent concomitant extrahepatic bile duct resection and consecutive hepaticojejunostomy. The median operation time was 374 min (range, 278 to 583). Intermittent Pringle maneuver was used in three patients with 31, 69, and 82 min, respectively. Total vascular exclusion was performed in one patient for 15 min because of partial resection of the IVC. Transfusion of red blood cells was necessary in two patients with 500 ml each. The histological examination showed that there was no residual tumor (R0). (Table 1).

Postoperatively, one patient suffered from postoperative biliary leak required a reoperation (Clavien-Dindo classification grade IIIB). No complication was observed in the other four patients. There was no PHLF. The median hospital stay was 11 days (range, 9 to 23). The median follow-up was 21 months (range, 14 to 61). The patient with benign biliary tumor in the final histology is still alive at the 61st postoperative month (POM). The patient undergoing ELH with palliative intension for HCC died at POM 4 due to known pulmonary metastases. Two of three patients with IHCCA, having positive lymph nodes at the surgery, died at POM 14 and POM 18 respectively due to disseminated tumor disease. The patient without lymph node metastasis survived 57 months despite of intrahepatic recurrence at POM 18 (Table 1).

Discussion

Modern liver surgery intends to achieve a complete tumor removal (R0 resection) with minimal morbidity and mortality. The functioning volume of the remnant liver is one of the key parameter in decision making for a safe and efficient liver resection. In patients undergoing left trisectionectomy, liver parenchyma-sparing has not been reported yet [4–6, 13, 14]. The authors proposed that when S5 is not involved by the tumor, preserving S5 is technically feasible. The S5-sparing ELH could be achieved by individual management of its venous outflow while the vascular inflow as well as the biliary outflow is intact in this situation.

The main target of parenchymal sparing hepatectomy (PSH) is to assure well−perfused larger volume of FLR with an adequate outflow in order to minimize postoperative morbidity and mortality [17]. Beside longer operative duration and more blood loss for PSH, the main technical challenge is maintaining adequate blood flow and biliary drainage in the FLR. To spare S5 with concomitant resection of S8, the

Table 1 Demographic data, surgical, and oncological results of the five patients undergoing S5-sparing extended left hepatectomy

	Gender age (year)	Primary Diagnosis	Segments involved	Veins Tumor involved	MHV	V5 drains into	OP time	Blood Transfusion (ml)	ICU (day)	Hospital stay (day)	DFS (month)	OS (month)	PO complications	Resection margin	Tumor staging* and grading
1st Case	Female 70	IHCCA	S1-S4, S8	LHV, S8 HV	Preserved	MHV	583	500	6	27	61	61	IIIB biliary leak	R0	Biliary mucinous cystadenoma
2nd Case	Male 59	HCC	S2-S4, S8	LHV, S8 HV	Preserved	MHV	278	0	1	9	0	4	no	R0	T3aNxM1G3. HCC
3rd Case	Female 79	IHCCA	S1-S4, S8	LHV, MHV	Resected	RHV	374	500	1	11	18	57	no	R0	T3N0M0 G2 (IHCCA)
4th Case	Male 65	IHCCA	S1-S4, S8	LHV, MHV	Resected	RHV	371	0	1	9	4	18	no	R0	T2bN1M0 G2 (IHCCA)
5th Case	Male 44	IHCCA	S1-S4, S8	LHV, MHV	Resected	MHV	392	0	2	13	4	14	no	R0	T2bN1M0 G3 (IHCCA)

*Tumor Staging: Based on 7th edition of American Joint Committee on Cancer

LHV left hepatic vein, *S* segment, *OP* operation, *ICU* intensive care unit, IHCCA intrahepatic cholangiocarcinoma, *HCC* hepatocellular carcinoma, *HV* hepatic vein, *MHV* middle hepatic vein, *DFS* disease-free survival, *OS* overall survival, *PO* post-operative

critical aspect is at the S5 venous outflow but not the portal or arterial inflow or biliary drainage. Generally, S5 is drained by venous tributary of the MHV [8]. But there is communication through venous tributaries between the MHV and the RHV to prepare for incidental occlusion of the MHV or the RHV [16]. Moreover, some forms of venous outflow reconstruction are performed to the FLR in case of segment congestion after PSH to maintain adequate outflow in a certain percentage of patients [15].

In our five patients, whom left trisectionectomy was indicated, S5-sparing ELHs were successfully carried out. These patients had no tumor involvement of S5. The management of the venous outflow was tailored according to the preoperative imaging study as well as the IOUS examination. Three patterns could be summarized as the following:

1) The MHV was free of tumor with sufficient safety resection margin in the 1st and 2nd cases. V5 was draining into MHV, so S8 with its venous stump were resected together with left hemi-liver while the main trunk of MHV was spared for S5 outflow (Fig. 2).
2) In the 3rd and 4th cases, the MHV was occluded by the tumor while S5 was drained by the RHV. So S5 sparing ELH with MHV trunk resection could be safely carried out without interfering with S5 outflow (Fig. 3).
3) In the 5th case, V5 was draining into the MHV which was invaded by the tumor. S5-sparing ELH was performed, and the MHV main trunk has been resected together along with S8 while V5 was secured with vascular clamp. There was no significant duskiness of S5 even when no venous reconstruction was performed. We refer that to the probability of communicating veins between the MHV and the RHV [15, 16] that could have alleviated the congestion of the right anterior section when the MHV is resected (Fig. 4a, b).

On early postoperative follow-up, no venous outflow obstruction was observed in all cases. All patients have neither developed postoperative ascites, nor was S5 congestion evident radiologically.

Because the postoperative localized venous congestion is highly related to venous anatomy [17], the authors propose a tailored management of S5 venous outflow. Additional to these three scenarios mentioned above, the fourth scenarios would be a venous reconstruction of the S5 vein in the case that parenchymal congestion is evident. In extended liver surgery in oncological settings, venous reconstruction of the remnant liver in addition to maintaining one of the three major hepatic veins to avoid congestion was advocated by some authors [9, 18], especially when the remnant liver has underlying liver disease or volume is critical. The decision for hepatic venous reconstruction could be supported by an exact volumetric analysis of potentially

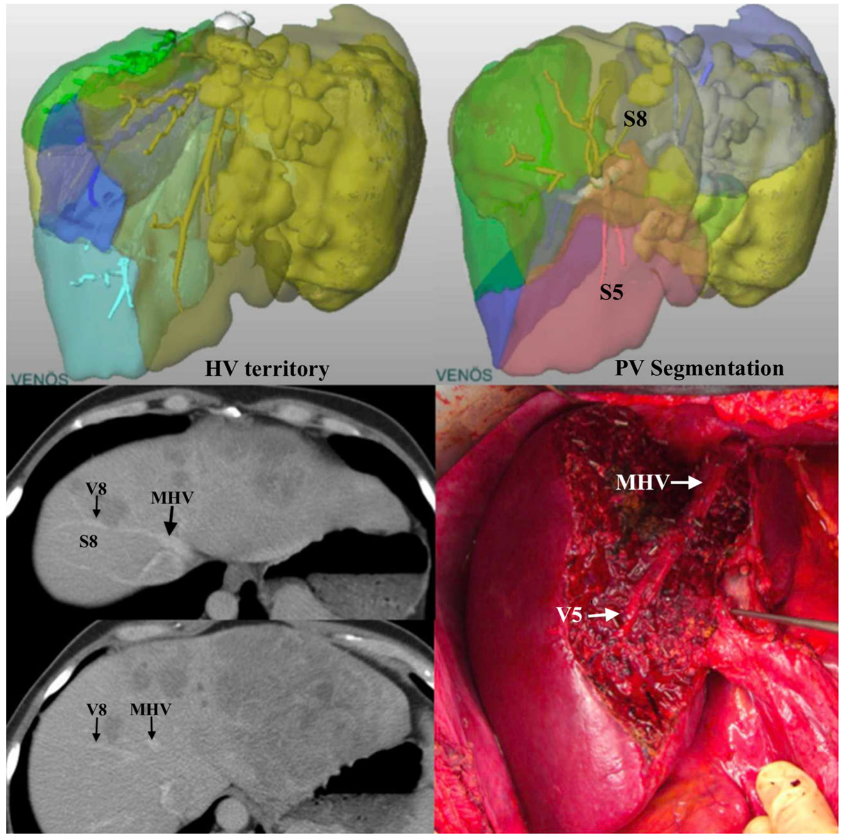


Fig. 2 The preoperative CT showed that the tumor involved the segment 8 (S8) vein but not the middle hepatic vein (MHV). Thus, the main trunk of the MHV could be preserved with resection of the S8 branches. The intraoperative ultrasound and 3D reconstruction study of the CT scan showed that the venous tributary of segment 5 (V5) drains into MHV

devascularized hepatic parenchyma [18]. However, till now, there is no consensus about the additional venous outflow reconstruction when one of the three main hepatic veins is kept intact.

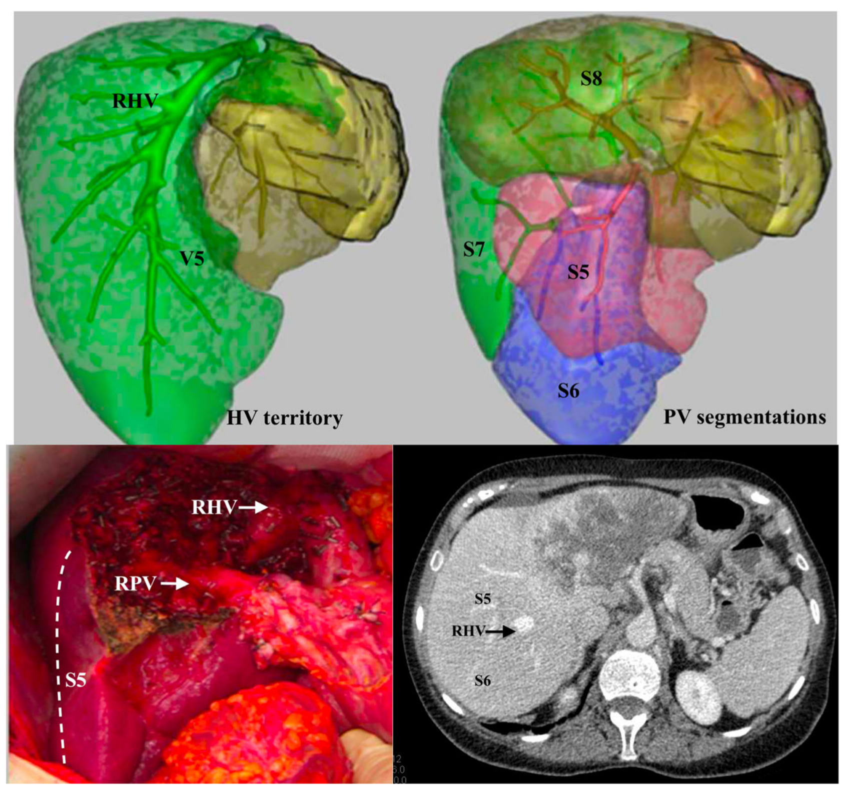


Fig. 3 The preoperative CT showed that the middle hepatic vein (MHV) was already occluded by the tumor (upper left). The segment 5 venous outflow through the right hepatic vein (RHV) was confirmed in the intraoperative ultrasound and 3D reconstruction study of the CT scan. The portal territories were shown (upper right)

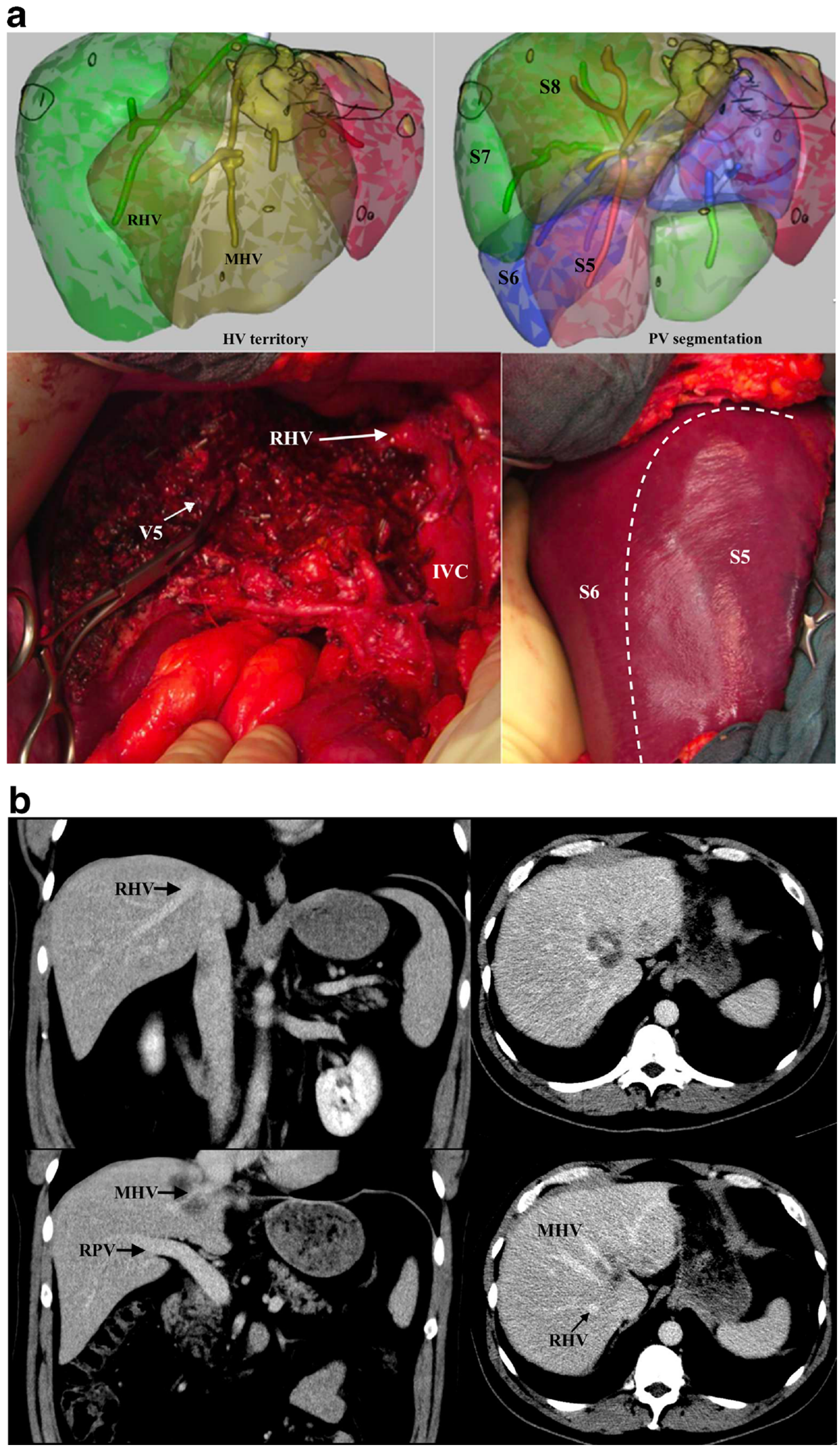


Fig. 4 Resection of the main trunk of the middle hepatic vein (MHV) but not the venous tributary of segment 5 (V5) was performed according to the preoperative CT study (**b**). A vascular clamp was kept in segment 5 for an optional reconstruction which was found not necessary at the end of operation. The 3D reconstruction study of the CT scan and intraoperative ultrasound showed that V5 drains into MHV (**a**)

We would like to underline that parenchyma-sparing surgery described in this article was built on the liver segmentation of Couinaud but not the true anatomical liver segmentation according to the portal territories. The liver segmentation system, described by Couinaud, is based on the identification of the three hepatic veins and the plane passing by the portal vein bifurcation, which are the main elements to define the superior segments (S8 and S7) and the inferior segments (S5 and S6) [19, 20]. In more complex liver surgery, traditional eight-segment scheme is insufficient and more tailored territorial liver resections is performed [21–23]. In ELH described in this study, the lateral border of segment 8 was set by the projection of RHV, which may not be the true anatomical segment 8 boundary. A preoperative 3D reconstruction could be helpful in the surgical planning by precisely describing portal territories and hepatic veins branches [24]. Several

Table 2 The liver volume changes after segment 5-sparing extended left hepatectomy

Patient	FLR1 (ml)-FLR1/TLV (%)	FLR2 (ml)-FLR2/TLV (%)	BW (kg)	FLR2/BW	Volume gain by S5 sparing
1st Case	320 (20.5%)	489 (31.3%)	68	0.72%	52.8%
2nd Case	414 (23.8%)	691 (39.7%)	70	0.99%	66.9%
3rd Case	474 (43.6%)	635 (58.4%)	52	1.22%	40.0%
4th Case	737 (42.5%)	1127 (64.9%)	85	1.33%	52.9%
5th Case	542 (36.7%)	681 (46.1%)	94	0.72%	25.6%

BW body weight, *FLR* future liver remnant, *FLR1* FLR without segment 5 sparing, consisted of segments 6 and 7, *FLR2* FLR with segment 5 sparing, consisted of segments 5, 6, and 7, *S5* segment 5, *TLV* total liver volume

new intraoperative techniques such as combined use of contrast-enhanced ultrasonography imaging using a sonazoid and fluorescence navigation system with indocyanine green during anatomical hepatectomy are adopted in many hepatobiliary centers. The combined use of these methods helps in evaluation of liver segment blood flow and allows simultaneous visualization of biliary canals, liver segments, as well as liver tumors [25, 26]. Unfortunately, these techniques were available at our center.

Despite of the low morbidity, nil mortality, and relative short hospital stay in this preliminary case series, the potential benefit of avoiding PHLF could not be confirmed due to small sample size, retrospective nature, and lack of a control group. We suggest further studies with larger sample size to evaluate the outcome of this procedure.

In conclusion, S5-sparing ELH is technically feasible. Under the tailored management of S5 venous outflow, the functional future liver remnant can be increased. Further studies with larger sample size are needed to evaluate in which circumstances the liver segment 5 could be preserved without venous reconstruction during the left extended hepatectomy. A preoperative 3D reconstruction could be helpful in the surgery planning, not only to guide the management of venous outflow in FLR, but also to ensure a sufficient safety margin.

Authors' Contributions J. Li: study conception and design, acquisition of data, analysis and interpretation of data, drafting of manuscript, critical revision of manuscript. M. Moustafa: study conception and design, acquisition of data, analysis and interpretation of data, drafting of manuscript, critical revision of manuscript. L. Fischer: study conception and design, analysis and interpretation of data, critical revision of manuscript. B. Nashan: study conception and design, analysis and interpretation of data, critical revision of manuscript.

Compliance with ethical standards

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

Ethical approval All procedures performed in studies were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments.

Informed consent Informed consent was obtained from all individual participants included in the study.

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