

Original Article

Image classification of liver cancer surrounding right hepatic pedicle and its guide to precise liver resection

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Abstract: Purpose: The aim of this study was to explore the feasibility of image classification of liver cancer surrounding right hepatic pedicle (RHP) and its guide to precise liver resection. Methods: Twenty-five patients with single liver cancer surrounding RHP were collected. According to the adjacent relationship between neoplasm and RHP shown in CT or MRI, the liver neoplasms were divided into the 4 types, type A neoplasm infiltrating or surrounding RHP, type B neoplasm locating in the anterior side of RHP, type C neoplasm locating in the dorsal side of RHP and type D neoplasm locating between the two branches. On the basis of image classification, operation project including hepatic vascular occlusion (HVO) and surgical resection procedure was designed. In the end, preoperative classification and surgical design was compared with operative results. Results: The locations of liver neoplasms were completely in line with preoperative classification. The methods of HVO and range of surgical resection were essentially coincident with preoperative plan. Pringle maneuver, total hepatic and hemihepatic vascular occlusion were applied. Four patients with type A neoplasms underwent right hemihepatectomy or extended right hepatectomy. Seven with type B received right anterior lobectomy or mesohepatectomy. Six with type C underwent segment V, VI resection, and eight with type D received right anterior or posterior lobectomy. All operations were smoothly finished. Conclusion: Preoperative classification guided by RHP can provide the accurate location information for liver cancer surrounding RHP, contribute to choosing suitable method of HVO and reasonable range of hepatic resection for precise surgery.

Keywords: Liver neoplasm, right hepatic pedicle, precise liver resection, hepatic vascular occlusion

Introduction

With the development of the surgical concept and technique, modern surgery has transformed from experiential models to precise ones during the past two decades [1]. The most influential belongs to precise liver resection, which includes modern imaging techniques, quantitative measurement of hepatic reserve function, digital surgical platform, improvement of traditional surgeries and careful nursing. Relying on a series of modern scientific theories and technologies, precise hepatectomy aims to completely eliminate target lesions, retain enough volume of remnant liver, control operation hemorrhage and finally gain the best rehabilitation in patients [1-3].

Modern medical imaging technology, especially three-dimensional (3D) analysis technique, could provide important information for deciding the resectability of hepatic lesions, opera-

tive indications and surgical plans [4-6]. Intraoperative navigation [4, 5], including ultrasound navigation [7-9] and the dye injection method [1, 10], could improve the safety and precision of liver resection. Middle hepatic vein (MHV) was often used as a guide or anatomic landmark during liver surgery [11-13]. However, the need for a precise alignment between the preoperative imaging data and the intraoperative situation remains to be adequately addressed because the liver is subject to deformation resulting from intraoperative manipulation and respiratory movements during the surgical procedures [5, 14]. In addition, 3D technique or intraoperative navigation system has not been applied generally in liver surgery, especially in developing countries. For most surgeons, only conventional imaging data could be utilized to distinguish the spatial relation between tumor locations, liver vessels and liver segments such as ultrasound, computer tomography (CT) and magnetic resonance imaging

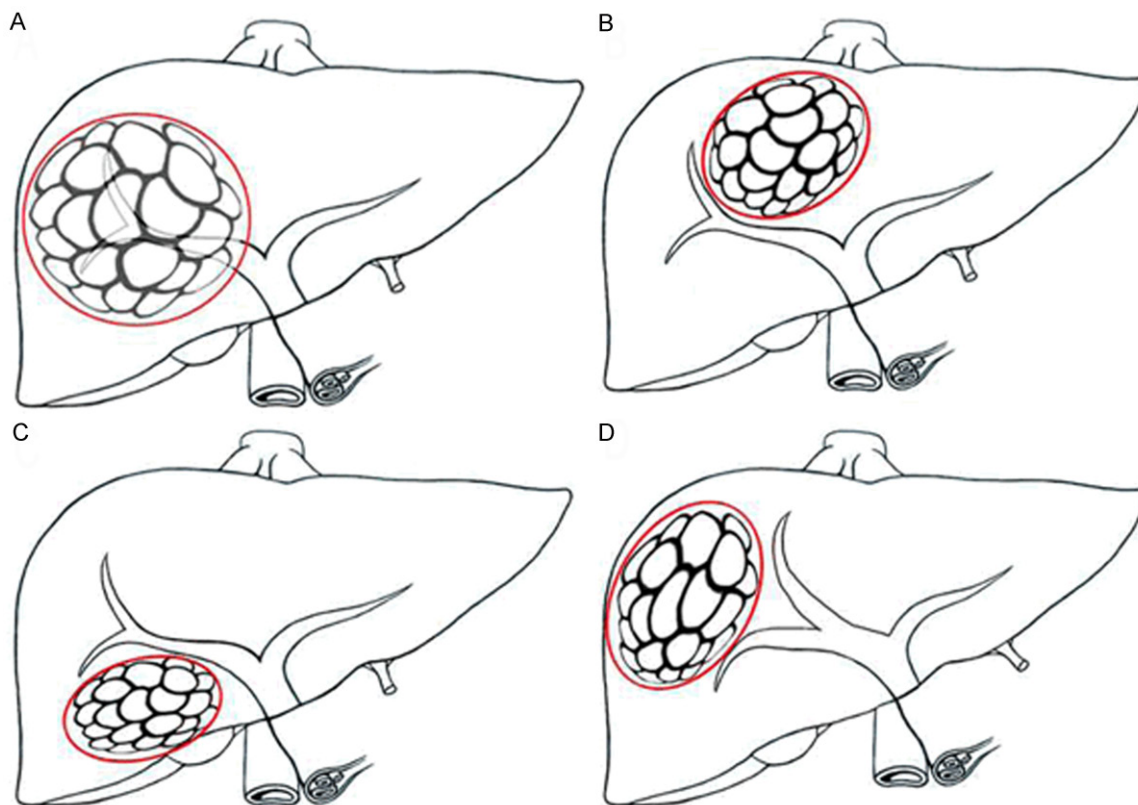


Figure 1. Method of image classification of liver neoplasm surrounding RHP. According to the adjacent relationship between neoplasm and RHP, the liver neoplasms were divided into 4 types. A. Neoplasms infiltrated or encased RHP (type A). B. Neoplasms located in the anterior side of RHP without invasion (type B). C. Neoplasms located in the dorsal side of RHP without invasion (type C). D. Neoplasms located between the two branches (type D).

(MRI) before operation. On the other hand, most liver neoplasms involve numerous vessels due to the complex anatomy of liver, and MHV is not the only anatomic landmark in liver surgery. It is possible that there exist some other anatomic landmarks in liver resection. In fact, lots of liver neoplasms adjoin, surround and even invade the right hepatic pedicle (RHP) or its branches in clinic, and RHP might be used as an anatomic landmark in liver surgery.

The present study reviewed 25 patients with liver neoplasm surrounding RHP who underwent hepatectomies between Jan 2009 and Dec 2013 in Department of Hepatobiliary Surgery, Affiliated Yijishan Hospital of Wannan Medical College, China. The liver neoplasms were divided into 4 types according to the adjacent relationship between neoplasm and RHP shown in CT or MRI, and resected anatomically using various hepatic vascular occlusions (HVO). The results were verified by operation. The aims of this report were to explore the feasibility of image classification of liver neoplasm

surrounding RHP and analyze its guiding significance to precise liver resection.

Patients and methods

Patients

Twenty-five patients (17 males and 8 females) were included in the present study. The patients ranged in age from 32 to 72 years with mean age 52 years. Preoperative CT or MRI showed all patients suffered from a single neoplasm surrounding RHP, which ranged from 5 to 15 cm in diameter with mean diameter 6.8 cm. The etiologies of underlying liver diseases were hepatocellular carcinomas (HCC) in 19 patients and cholangiocarcinomas (CC) in 6. No cancer embolus was found in portal vein and inferior vena cava. None of the patients had received preoperative chemo- or embolic therapy. Liver cirrhosis was detected in 17 patients. Twenty-one patients were in Child's class A, and four in class B which returned to normal after drug treatment. All patients underwent hepatic resection.

Image classification of liver cancer surrounding RHP and precise liver resection

Table 1. Liver tumor classification, location and hepatectomy procedures (cases)

Classification (n)	Location/scope(n)	Hepatectomy procedures (n)
Type A (4)	Right hemiliver (3)	Right hepatectomy (3)
	Right hemiliver and S IV (1)	Extended right hepatectomy (1)
Type B (7)	Right anterior lobe (2)	Right anterior sectionectomy (2)
	Right anterior lobe and S IV (5)	Mesohepatectomy (5)
Type C (6)	S VI (2)	Resection of S VI (2)
	S V (2)	Resection of S V and S VI (2)
	S V and caudate lobe (2)	Resection of S V, S VI and caudate lobe (2)
Type D (8)	Right anterior lobe (3)	Right anterior sectionectomy (3)
	Right posterior lobe (5)	Right posterior sectionectomy (5)

Abbreviations: S IV: segment IV; S V: segment V; S VI: segment VI.

Method of image classification

According to the adjacent relationship between liver neoplasm and RHP shown in CT or MRI, the liver neoplasms were divided into following 4 types, type A neoplasms infiltrating or encasing RHP; type B tumors locating in the anterior side of RHP, which do not invade RHP; type C neoplasms locating in the dorsal side of RHP, which also do not invade RHP; and type D locating between the two branches (**Figure 1**).

Operation scheme

The methods of HVO and ranges of surgical resection were designed, mainly according to preoperative image classification and liver function. Right hepatectomy could be performed if a type A neoplasm did not go beyond right liver. Extended right hepatectomy should be considered if a type A tumor invaded left medial lobe. Right anterior sectorectomy could be the best option if a Type B neoplasm was restricted to right anterior lobe. Mesohepatectomy should be a priority when a Type B tumor infiltrated left medial lobe. Resection of segments V (S V) and/or VI (S VI) was suitable for Type C neoplasms, and right anterior or right posterior sectorectomy could be used for Type D tumors.

Pringle maneuver should be applied if the neoplasm went beyond half liver or was accompanied with cavernous transformation of portal vein. If tumor oppressed or invaded inferior vena cava (IVC), total hepatic vascular exclusion (THVE) could be considered. As for hemihepatectomy, hemihepatic vascular occlusion (HHVO) should be the first priority, especially in patients with liver cirrhosis or patients whose postoperative liver function was difficult to

recover by estimation. Intrahepatic segmental vascular occlusion was suitable for tumors that were limited to one lobe. Right hepatic vein (RHV) blockage could be applied when it is necessary.

Operation methods

Informed consent was obtained from all patients for hepatic resection. The patient was placed in the supine position. Laparotomy is performed through an upper midline incision with right lateral subcostal extension (reversed L-shaped incision) to detect the tumor location, size and potential metastasis. If the tumor could be resect by preliminary estimation, the xiphoid process is then excised, and the hepatic ligaments were divided for further understanding the adjacent relationship between tumor and major vessels including RHP. In the end, tumor classification, range of surgical resection and method of HVO were defined.

Hepatic resection was then performed according to the final tumor classification and corrected operation plan. Hepatic hilum, supra -and infra-hepatic inferior vena cava (IVC) were dissected, encircled and taped if necessary, respectively. The right Glissonean pedicle could be dissected and encircled or ligated extrahepatically when hemihepatectomy was performed. If it was necessary to use segmental vascular occlusion, the right anterior or posterior Glissonean pedicle should be detached and encircled extrahepatically after cystic plate was dissected [15]. Sometimes RHV should be isolated for hepatic blood outflow occlusion. Using above vascular occlusion, a parenchymal dissection was performed along the demarcation line using curettage-aspiration dissection

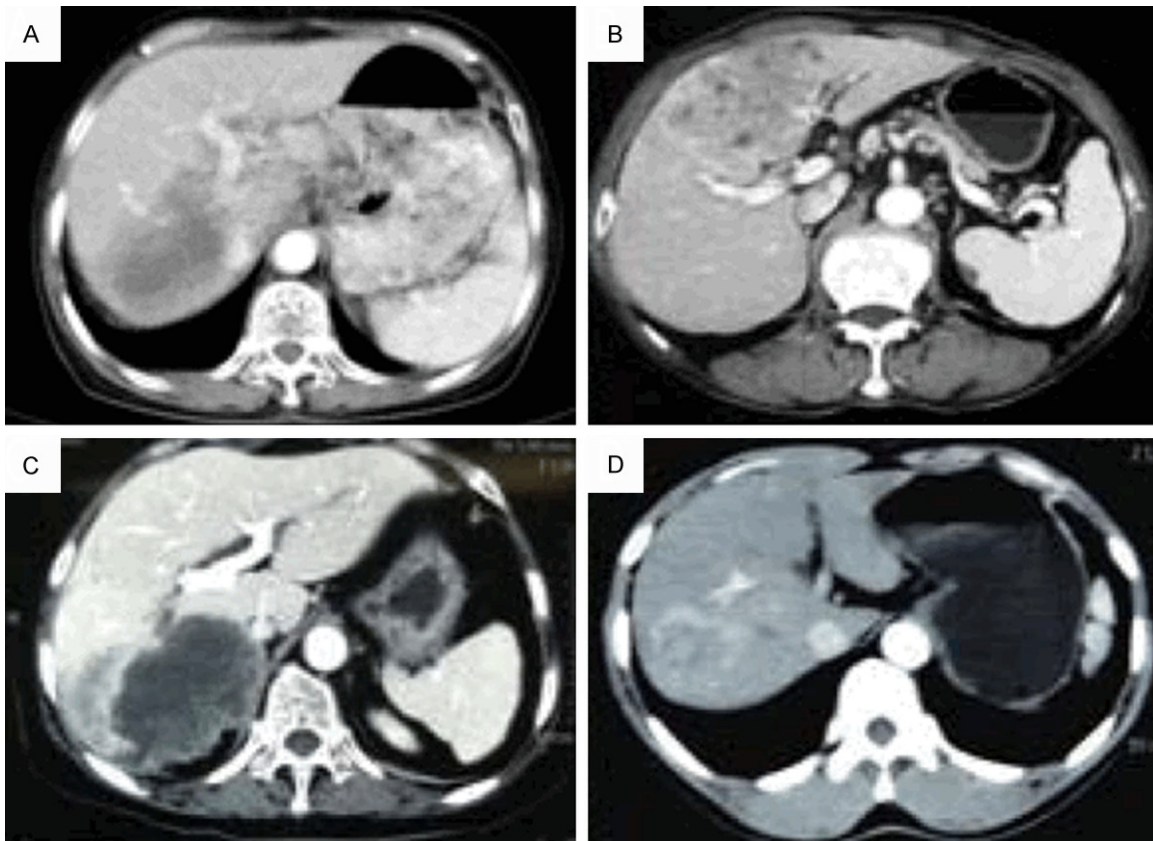


Figure 2. Preoperative image classification of liver neoplasm surrounding RHP. According to the adjacent relationship between neoplasm and RHP shown in CT or MRI, twenty-five patients with liver neoplasms surrounding RHP included 4 cases with type A neoplasms (A), 7 with type B (B), 6 with type C (C) and 8 with type D tumors (D).

technique with Peng's multifunction operative dissector [16].

Observation indexes

Intraoperative tumor classification, range of liver resection, method of HVO, operation time, intraoperative hemorrhage volume, amount of blood transfusion, postoperative complications and recovery are observed. Preoperative image classification and surgical design were compared with the operative results. All patients were followed up at regular intervals for a mean period of 19 months (range from 12 to 48 months).

Results

Intraoperative tumor classification

All patients were proved to suffer from a single liver neoplasm. The locations of liver neoplasms were completely consistent with preoperative image classification (Table 1). According to the image classification, there were four cases with type A neoplasms, seven with type

B, six with type C and eight with type D tumors, respectively (Figure 2).

Techniques of hepatic vascular control

Methods of hepatic vascular control were basically consistent with operation project. Pringle maneuver was used in ten patients including one with type A neoplasm, four with type B, two with type C and three with type D tumors. THVE was performed for one patient with type A tumor, one with type B and two with type C neoplasms. Right HHVO was applied in eleven patients including two with type A neoplasms, two with type B, two with type C and five with type D tumors. Of the eleven patients, extraparenchymal control of RHV was used in three cases.

Hepatectomy procedures

Various anatomical liver resections were selected according to tumor classification, liver function and local anatomical properties. Four patients with type A neoplasms underwent

Image classification of liver cancer surrounding RHP and precise liver resection

right hepatectomy (3) or extended right hepatectomy (1), respectively. Seven patients with type B tumors received right anterior sectionectomy (2) or mesohepatectomy (5), respectively. Six patients with type C neoplasms underwent resection of SV and S VI (2), resection of S VI (2) or resection of SV, S VI and hepatic caudate lobe (2), respectively. Other eight patients with type D tumors received right anterior (3) or right posterior sectionectomy (5), respectively (**Table 1**).

All operations were smoothly finished without major vascular injury and other serious complications. The operation time ranged from 110 to 200 min with an average of 145 min. The median surgical blood loss was 290 mL (range: 180-700 mL). Eight patients received intraoperative blood transfusion. The amounts of blood transfusion ranged from 300 to 600 mL with an average of 420 mL.

Postoperative situation

All patients had a good recovery of postoperative liver function. Postoperative complications included pleural effusions in 3 patients and bile leakages in 2. Both pleural effusions and bile leakages were cured by thoracocentesis or drainage. Postoperative pathological report showed 19 cases of HCC and 6 cases of CC. Seventeen patients (68.0%) were accompanied with liver cirrhosis and 5 (20.0%) with fatty liver. Retroperitoneal lymph nodes metastases found in 2 patients with CC in the postoperative 10th and 15th months, respectively. Postoperative intrahepatic recurrences were found in 3 patients with HCC in the postoperative 16th, 18th and 26th months, respectively. Four of the five patients died in postoperative 3 years. Other patients gained tumor free survival.

Discussion

Relying on the current highly-advanced biomedicine and information technology, precise liver resection covers a firenew conception of liver surgery and pursues the best balance among complete elimination of target lesions, liver protection and control of systemic tissue damage. Its main contents include accurate preoperative evaluation, precise operation project, sophisticated intraoperative techniques and excellent postoperative management [1-3]. Accurate preoperative evaluation is the premise and basis of precise liver resection, and sophisticated surgical techniques is a guaran-

tee for successful outcome. In this study, liver tumors surrounding RHP were classified according to the relationship between liver neoplasm and RHP shown in preoperative CT and MRI. Based on preoperative image classification, preliminary operation projects were designed and precise liver resections guided by RHP were performed. The clinical practice of 25 patients proved that the preoperative image classification could reveal the exact location of liver tumor, which could be used not only to provide an important basis for the choice of HVO but also to contribute to determine the range of precise liver resection.

Modern hepatectomy is based on Couinaud's liver segmentation, which depends on the hepatic vessel anatomy, so the imaging study of hepatic vessels is very important for liver surgery [1]. Of numerous vessels of liver, the most meaningful anatomic landmarks include MHV and the first porta hepatic (FPH) which is divided into the left hepatic pedicle (LHP) and RHP. On the other hand, right liver normally occupies more than half of liver volume, and more than half of liver neoplasms adjoined, infiltrated and even encased RHP or its branches. These tumors are known as liver neoplasm surrounding RHP. Hepatectomy for these neoplasms is relatively difficult and complicated. Therefore, preoperative precise evaluation is very important, which could contribute to the design of operation project, choice of HVO and determination of liver resection procedure. In this study, liver neoplasms in 25 patients were divided into four types according to the relationship between liver neoplasm and RHP, and operative exploration proved that the locations of liver tumors were in full accord with preoperative image classification. Due to the complexity of liver anatomy and surrounding vessels, these tumors not only adjoined to RHP but also approached or invaded IVC, LHP and even the second hepatic portal (SHP). Hence, it could be further divided into several subtypes. For instances, type A neoplasms can be divided into IVC infiltrated type, the SHP infiltrated type and both un-infiltrated type. Type B tumors conclude LHP infiltrated type and LHP un-infiltrated type. The resection of these liver neoplasms with different subtypes should use different methods of HVO and hepatic surgery. Therefore, a more elaborate classification for these liver neoplasms contributes not only to understanding the relationship between liver neoplasm

Image classification of liver cancer surrounding RHP and precise liver resection

and major vessels, but also to designing more precise operation project.

Precise liver resection is required to minimize intraoperative hemorrhage as far as possible, and reasonable application of HVO is the main strategy. Every hepatic vascular control technique has its place in liver surgery, depending on tumor location, underlying liver disease, liver function, and, most important, the experience of the surgical and anesthesia team. Preoperative image classification can provide an important basis for choice of HVO. Pringle maneuver so far is still the most common and effective temporary method to block hepatic blood inflow and minimize intraoperative hemorrhage [1]. Pringle maneuver was more frequently applied in the early stage of this study. In the latter period, the maneuver was used only when there existed cavernous transformation of the portal vein or neoplasm exceeded the boundaries of half liver. Its disadvantages were hepatic venous bleeding and hepatic ischemia-anoxia, which can delay the recovery of postoperative liver function [17, 18]. Because most neoplasms located in the right liver in this study, right HHVO was more frequently adopted in the later stage. After hilar plate was anatomized above the bifurcation of common hepatic duct, the right Glissonean pedicle could be detached and encircled extrahepatically to control right hepatic blood inflow [19, 20]. If right hemihepatectomy was needed, the right hepatic artery, right branch of portal vein and right hepatic duct could be extrahepatically dissected and transected in advance, respectively. Of course, the right portal pedicle could be also transected after liver parenchyma transaction was finished. If it was necessary to block further the blood inflow of right anterior or posterior lobe, the right anterior or posterior Glissonean pedicle should be detached and encircled extra-hepatically by dissecting the cystic plate [21]. The segmental vascular occlusion was seldom applied in liver surgery because of its relative complexity and bleeding risk. The hemihepatic or segmental vascular occlusion offers obvious demarcation of the resection limits, protects the remnant liver from ischaemia, and avoids splanchnic congestion and haemodynamic consequences, so it is particularly suitable for patients with liver cirrhosis [22]. Nevertheless, both methods can not control backflow bleeding from the hepatic veins. When the tumor infiltrates the IVC or caval-hepatic junction, THVE may be applied

[21]. THVE not only creates conditions for surgeon to repair, resect and anastomose IVC but also controls backflow bleeding of hepatic veins. However, THVE is not recommended in most cases because it is associated with haemodynamic intolerance in 10%-20% of patients and requires strict haemodynamic monitoring and anesthetic expertise [21].

In recent years, we frequently used HHVO combined with control of RHV according to the location characteristic of liver neoplasm surrounding RHP. This method was similar with selective hepatic vascular exclusion (SHVE) or hepatic vascular exclusion with preservation of the cava flow (HVEPC) [18, 23]. But the RHP and RHV should be blocked with FPH untouched in our method. The new method has little effect on internal environment and liver function because it avoid haemodynamics disorder caused by FPH or/and IVC blockage. Therefore, we think our new method conforms to the concept of precise liver resection and the principle of minimally invasive surgery. In fact, there is little liver neoplasm infringing IVC really, and HHVO combined with control of RHV can control hemorrhage effectively in most cases.

During precise liver resection, they are necessary to determine reasonable surgical resection range and select best liver transection plane for complete elimination of target lesions and smooth recovery of postoperative liver function. There should be no important vascular structure on liver transection plane for the safety of hepatectomy [1]. In this study, right hepatectomies were performed for 3 patients with type A neoplasms whose tumors located in the right liver. Extended right hepatectomy was carried out for 1 patient with type A tumor invading left medial lobe. Right anterior sectorectomies provided the best option for 2 cases with Type B neoplasm locating in right anterior lobe, and mesohepatectomies were performed for 5 Type B patients whose neoplasms infiltrated left medial lobe. Type C neoplasms may be located in segment V or/and VI, and even invade the caudate lobe. Six patients with Type C tumors underwent resection of SV, SVI or combined with caudate lobe. Right anterior or posterior sectorectomies were performed for 8 patients with Type D tumors. In addition, precise liver resection demands that vessels in liver cross section should be precisely anatomized and properly handled. In this

study, hepatic resections were performed using curettage-aspiration dissection technique with Peng's multifunction operative dissector [16]. All neoplasms were anatomically resected guided by RHP. The resection ranges were completely in line with preoperative project, and all important un-infiltrated vessels had been protected. Postoperative liver function of patients recovered smoothly.

Conclusion

Preoperative image classification guided by RHP can provide the accurate location information for liver neoplasm surrounding RHP, contribute to choosing suitable method of HVO and reasonable range of hepatic resection in precise liver resection.

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Disclosure of conflict of interest

None.

Abbreviations

3D, three-dimensional; MHV, middle hepatic vein; CT, computer tomography; MRI, magnetic resonance imaging; RHP, right hepatic pedicle; HVO, hepatic vascular occlusion; SIV, segment IV; SV, segment V; SVI, segment VI; IVC, inferior vena cava; THVE, total hepatic vascular exclusion; HHVO, hemihepatic vascular occlusion; RHV, Right hepatic vein; TACE, Transcatheter hepatic arterial chemoembolizations; FPH, first porta hepatic; LHP, left hepatic pedicle; SHP, second hepatic portal.

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Image classification of liver cancer surrounding RHP and precise liver resection

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