

ORIGINAL ARTICLE

# The role of three-dimensional imaging in optimizing diagnosis, classification and surgical treatment of hepatocellular carcinoma with portal vein tumor thrombus

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## Abstract

**Background:** Accurate assessment of characteristics of tumor and portal vein tumor thrombus is crucial in the management of hepatocellular carcinoma.

**Aims:** Comparison of the three-dimensional imaging with multiple-slice computed tomography in the diagnosis and treatment of hepatocellular carcinoma with portal vein tumor thrombus.

**Method:** Patients eligible for surgical resection were divided into the three-dimensional imaging group or the multiple-slice computed tomography group according to the type of preoperative assessment. The clinical data were collected and compared.

**Results:** 74 patients were enrolled into this study. The weighted  $\kappa$  values for comparison between the thrombus type based on preoperative evaluation and intraoperative findings were 0.87 for the three-dimensional reconstruction group ( $n = 31$ ) and 0.78 for the control group ( $n = 43$ ). Three-dimensional reconstruction was significantly associated with a higher rate of en-bloc resection of tumor and thrombus ( $P = 0.025$ ). Using three-dimensional reconstruction, significant correlation existed between the predicted and actual volumes of the resected specimens ( $r = 0.82$ ,  $P < 0.01$ ), as well as the predicted and actual resection margins ( $r = 0.97$ ,  $P < 0.01$ ). Preoperative three-dimensional reconstruction significantly decreased tumor recurrence and tumor-related death, with hazard ratios of 0.49 (95% confidential interval, 0.27–0.90) and 0.41 (95% confidential interval, 0.21–0.78), respectively.

**Conclusion:** For hepatocellular carcinoma with portal vein tumor thrombus, three-dimensional imaging was efficient in facilitating surgical treatment and benefiting postoperative survivals.

Received 7 October 2015; accepted 12 October 2015

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This work was supported by the grants of the Science Fund for Creative Research Groups (No: 81221061); The State Key Project on Diseases of China (2012zx10002016016003); The China National Funds for Distinguished Young Scientists (No: 81125018); Chang Jiang Scholars Program (2013) of China Ministry of Education; China National Funds for National Natural Science (Nos: 81101511, 81472282).

Xu Biao Wei and Jie Xu contributed equally to this work.

## Introduction

Hepatocellular carcinoma (HCC) is the fifth most common cancer and the third-leading cause of cancer-related death in the world.<sup>1</sup> HCC has a great propensity to invade the portal venous system, leading to the formation of portal vein tumor thrombus (PVTT). PVTT is the most important poor prognostic factor, being found in 60–90% of patients diagnosed to have advanced liver cancer in China.<sup>2</sup> Although Sorafenib was recommended by the Barcelona Clinic Liver Cancer (BCLC) guideline as the only

therapy for these patients, recent studies have shown that surgical resection offers a more promising prognosis in selected HCC patients with PVTT.<sup>3–5</sup>

Before operation, the characteristics of the primary tumor and the PVTT should be carefully evaluated. The primary tumor should be resected with an adequate resection margin and an adequate residual liver remnant should be preserved to avoid postoperative liver failure. Moreover, the PVTT can either be en-bloc resected together with the primary tumor, or removed by thrombectomy according to its location and extent.<sup>6,7</sup> The evaluation of such an operation nowadays is usually done on conventional two-dimensional (2D) multiple-slice computed tomography (MSCT).

The recent development of three-dimensional (3D) reconstruction has been shown useful in preoperative planning for hepatectomy by providing precise information on the future liver remnant and the tumor-free margin.<sup>8–11</sup> 3D reconstruction offers better understanding of the tumor and PVTT characteristics when compared with 2D imaging. The aim of this study was to evaluate the role of 3D reconstruction in optimizing diagnosis and surgical treatment of HCC patients with PVTT, when compared with conventional 2D MSCT.

## Patients and methods

This non-randomized cohort study with prospectively collected data was carried out retrospectively in the Eastern Hepatobiliary Surgery Hospital, Shanghai, China, from June 2012 to June 2014. The study was approved by our Institutional Review Board and written informed consent was obtained from all patients for their data to be used for clinical research.

The diagnosis of HCC was based on the noninvasive criteria in accordance with the European Association for the Study of Liver guidelines.<sup>12</sup> All HCC patients underwent routine three-phase dynamic MSCT examination after hospital admission. A diagnosis of PVTT was made when there was presence of low-attenuation intraluminal masses that expanded the portal vein, or when there were filling defects in the portal venous system as determined on MSCT images.

### Inclusion/exclusion criteria

The inclusion criteria were HCC patients aged from 18 to 70 years; presence of PVTT confirmed by preoperative MSCT examination; resectable lesion in the liver with adequate hepatic functional reserve as measured by imaging and laboratory tests. The exclusion criteria were patients with a previous history of other cancer; severe co-existing systemic disease; or had received previous chemotherapy or radiotherapy.

The 3D reconstruction was available in our center in June 2012. A detail discussion was made with all the patients on the pros and cons of the 3D imaging reconstruction, including the extra-time consumed on the procedure and the potential risk of

providing inaccurate information. Patients who consented to the 3D reconstruction were entered into the 3D reconstruction group. The remaining patients formed the MSCT group. The sole difference between the groups was determined by the patient's willingness to receive 3D reconstruction. The rest of the preoperative evaluation and the treatment strategy were the same throughout the study period.

### Process of spectral CT examination and 3D imaging reconstruction

The MSCT imaging provided the fundamental information for the 3D reconstruction process. The MSCT images were obtained using a spectral CT (Discovery CT750 HD, GE Healthcare, Milwaukee, USA). The scanning parameters used for the CT examination were as follows: a slice thickness of 1.25 mm, a pitch of 0.984 mm, a 0.6-sec scanning time per rotation, a table speed of 13.5 mm/rotation, and a reconstruction interval of 2 mm. After pre-contrast images were obtained, a triple-phase enhanced scan was performed. The enhanced scan used the spectroscopy scan mode (gemstone spectral imaging, GSI). 80 ml of the compound meglumine diatrizoate injection (Xudong Haipu Pharmaceutical Co, Ltd, Shanghai, China) were infused at a rate of 3.5 ml/s with a power injector. The arterial phase images were obtained at 5 s; the portal phase images at 20 s; and the venous phase images at 70 s after the peak aortic enhancement time.

For patients in the 3D reconstruction group, after the triple-phase contrast CT examination was performed, the image data sets obtained were analyzed using the 3D image processing software (3D Plus Body Visible System, Yorktal Medical, ShenZhen, China). The triple-phase CT images were transported into the 3D post processing system. The images of the tumor, portal vein, PVTT, hepatic vein, hepatic artery and liver parenchyma were extracted and reconstructed individually using a region-growing or level-set technique and were overlapped to create the integrated 3D images. The transparent display employed in the 3D simulation system provided perspective views of the liver and its surrounding vessels. Various functions which included display or hide of different anatomic structures, and rotation and enlargement, allowed detailed understanding of the characteristics of the tumor and the PVTT. All 3D reconstructions were completed within one working day.

### Preoperative assessment of the PVTT type

The PVTT was classified according to the Cheng's classification which has been shown to be effective in stratifying HCC patients with PVTT<sup>2,6,13</sup>: type I, tumor thrombus involving segmental or sectoral branches of the portal vein or above; type II, involvement of the right or left portal vein; type III, invasion of the main trunk of portal vein; and type IV, involvement of the superior mesenteric vein.

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