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• BRIEF REPORTS •

Three-dimensional contrast-enhanced MR angiography in diagnosis of portal vein involvement by hepatic tumors

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Abstract

AIM: To assess the accuracy of three-dimensional contrast-enhanced magnetic resonance angiography (3D CE MRA) in evaluation of the portal vein involvement in patients with hepatic tumors.

METHODS: 3D CE MRA was performed in 62 patients with hepatic tumors to assess the patency of the main, right and left portal veins before hepatic surgery. A total of 186 veins were examined for encasement, occlusion and tumor thrombosis. The results of 3D CE MRA diagnosis were then correlated with the surgical-pathological and intra-operative sonographic findings.

RESULTS: 3D CE MRA correctly detected 48 of 49 involved and 135 of 137 noninvolved portal veins with the sensitivity of 98 %, specificity of 99 %, positive predictive value of 96 % and negative predictive value of 99 %.

CONCLUSION: 3D CE MRA is accurate in evaluation of the portal vein involvement in patients with hepatic tumors.

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INTRODUCTION

Evaluation of the patency of the portal vein (PV) is essential before surgical resection of hepatic tumors. There are advantages and limitations to the conventional methods for PV imaging. Ultrasound (US) is noninvasive and relatively inexpensive, but it is operator dependent and may not be successful when the acoustic window is restricted[1,2]. Contrast-enhanced computed tomography (CT) is readily available and can demonstrate the PV, but it uses ionizing radiation and requires intravenous administration of a large amount of iodinated contrast medium with the risk of nephrotoxicity and possible allergic reaction[2-5]. X-ray portography is the standard technique for evaluation of the PV due to its superb spatial resolution[2], but it is invasive, uncomfortable and, like CT, involves radiation and use of iodinated contrast medium. Occasionally, opacity of the PV is poor by intra-arterial portography in patients with portal hypertension[2,6,7]. The disadvantages of x-ray portography also include high cost, requirement for operator expertise and associated complications such as hemorrhage and aortic dissection[8]. Non-enhanced magnetic resonance angiography (MRA) with time-of-flight (TOF) and phase-contrast (PC) techniques is another means for non-invasive demonstration of the PV. However, it is limited by long acquisition time, motion and flow artifacts and saturation effects[1,9-13].

Three-dimensional contrast-enhanced MRA (3D CE MRA) is a recently developed, non-invasive and fast and easy to perform technique which is suited for evaluation of the portal venous system[14-21]. With this technique, the imaging of the PV is accomplished in a single breath hold. It requires only a peripheral venous injection of a small amount of gadolinium, which is much safer than iodine-based contrast media. Using gadolinium to shorten the T1 value of the blood, it overcomes flow artifacts and saturation effects in TOF and PC. Moreover, it involves no radiation. 3D CE MRA has been frequently used in our hospital in patients with liver tumors for the preoperative diagnosis of the patency of the portal venous system. The goal of this study was to evaluate the accuracy of this technique for the assessment of the PV involvement in hepatic tumors.

MATERIALS AND METHODS

Patients

Sixty-two consecutive patients who required evaluation of their portal venous system before surgical resection of hepatic tumors were recruited. They consisted of 56 men and 6 women ranging in age from 26 to 78 years (mean age 54 years) and were diagnosed clinically as hepatocellular carcinoma (55 patients), hepatic metastasis (4 patients), hemangioma (1 patient), hepatic adenoma (1 patient) and right adrenal carcinoma with liver involvement (1 patient).

MR examinations

MR scans were performed using a 1.5T MR imager (Signa, General Electric Medical Systems, Milwaukee, WI, USA) and a body coil. After images located were acquired, a breath-hold T1-weighted fast multiplanar spoiled gradient-echo (FMPSPGR) sequence (repetition time/echo time, 150/4.2 ms; flip angle, 90°; field of view, 360 mm; matrix, 128×256; 18 slices of 7.0 mm thickness each; gap, 3.0 mm; one signal acquired) and a respiratory-triggered T2-weighted fast spin-echo sequence (repetition time/echo time, 2800-4200/80 ms; echo train length 8-12, field of view, 360 mm; matrix, 128×256; 18 slices of 7.0 mm thickness each; gap, 3.0 mm; 2 signals acquired) were performed in the liver. For 3D CE MRA, a breath-hold 3D fast spoiled gradient-echo sequence (repetition time/echo time, 5.2-10.2/1.2-1.9 ms; flip angle, 30° or 45°; field of view, 360-480 mm; matrix, 128×256; imaging volume, 75-168 mm; number of partitions, 24-30; one signal acquired; and acquisition time, 19-28 s) was used.

With T1-weighted and T2-weighted images as references the imaging volume of 3D CE MRA was acquired in a coronal plane to cover the main PV and its left and right intrahepatic branches. The imaging volume was determined by a radiologist depending on each patient's liver size and ability of breathholding. A gadolinium chelate called gadopentetate-dimeglumine (Magnevist; Schering AG, Berlin, Germany) was used as a contrast medium for all examinations, with a concentration of 0.15 mmol per kg body weight. The contrast medium was injected by an experienced MR technician through an antecubital vein at an injection rate of approximately 3 ml/s. Acquisition was commenced immediately after the injection and repeated three times with a 6-second delay between each acquisition to allow patient breathing. The second acquisition coincided with portal venous phase, while the first acquisition was the arterial phase and the third acquisition was the equilibrium phase. Source images of portal venous phase were reviewed first. These images were then reconstructed on a workstation (Advantage Windows Workstation, General Electric Medical Systems, Milwaukee, WI) to produce projectional images like x-ray portography. Both maximum intensity projection and multiplanar reconstruction techniques were performed and reviewed.

Image analysis

The patency of the main PV and intrahepatic left and right PV including their anterior and posterior branches on 3D CE MRA were assessed by two radiologists who were unaware of the patient's clinical status. A consensus reading between them was reached in every case. The PV involvement was considered to be present if the veins were encased, occluded and thrombosed. Encasement was diagnosed when the PV was surrounded by a tumor and showed mural irregularity or had an indistinct wall or irregular lumen narrowing. The PV was considered to be occluded if the lumen was obstructed, interrupted or not visualized due to tumor invasion. Tumor thrombosis was diagnosed when the PV was widened with linear, nodular or irregular filling defect.

Surgery was performed 1-20 days (mean, 6 days) after the MR imaging. Tumor location and portal venous status were recorded by the surgeon in the surgical report for each case. In 12 of 49 patients who underwent hepatic resection, tumor thrombi were removed from the stump and/or main trunk of the PV during the operation. In 13 patients whose tumors were found to be unresectable at surgery, intra-operative US was performed to demonstrate the PV. In these unresectable cases, small amount of tumor tissue was taken for pathological examination and 3 of them had tumor thrombi removed from the main PV. The results of 3D CE MRA for assessment of the PV involvement were compared with the surgeon's findings. Sensitivity, specificity, positive and negative predictive values of 3D CE MRA were calculated using surgical-pathologic and intra-operative US findings as the references. All cases with false positive and negative diagnosis were further analyzed to determine the cause of the error.

RESULTS

All 3D CE MRA examinations were performed successfully. The main PV and intrahepatic left PV and right PV including their anterior and posterior branches were shown well without diagnostic difficulty in each case.

Forty-nine of 186 PVs were found to be involved at surgery. Encasement was present in 7 veins, occlusion in 13 veins and tumor thrombosis in 29 veins (Figures 1-3). The site and type of the PV involvement were summarized in Table 1. The remaining 137 PVs were normal. 3D CE MRA correctly depicted 48 of 49 (98 %) involved PVs and 135 of 137 (99 %) noninvolved PVs with an overall sensitivity of 98 %, specificity of 99 %, positive predictive value of 96 %, and negative predictive value of 99 % for the evaluation of all PVs including the main, left and right PVs. The accuracy in examination of the patency of the main PV reached 100 %. The relationship between 3D CE MRA for each of the PVs and the surgical findings is shown in Table 2. Use of 3D CE MRA resulted in two false positive interpretations involving the left PV (Figure 4) and one false negative interpretation involving the right PV (Figure 5). The two false positive diagnoses were made in which the left PVs were interpreted as occluded at 3D CE MRA, whereas at surgery they were found to be compressed but not invaded by tumors in left lobes. For the false negative diagnosis, the right PV was diagnosed as normal by 3D CE MRA, but surgical-pathologic examination revealed that the right posterior PV was thrombosed with tumor.

Table 1 Surgical-pathologic findings of portal vein involvement

	Type of involvement				
	Total involved	Encasement	Occlusion	Tumor thrombosis	Normal
Main PV	12	0	0	12	50
Left PV	18	3	8	7	44
Right PV	19	4	5	10	43
Total	49	7	13	29	137

Note: Data are number of cases. PV is portal vein.

Table 2 Relationship between 3-dimensional contrast-enhanced MR angiography diagnosis of portal vein involvement and surgical-pathologic findings

	True positive	True negative	False negative	False positive	Sensitivity (%)	Specificity (%)	Positive predictive (%)	Negative predictive (%)
Main PV	12	50	0	0	100	100	100	100
Left PV	18	42	0	2	100	95	90	100
Right PV	18	43	1	0	95	100	100	98
Total	48	135	1	2	98	99	96	99

Note: Data are number of cases except otherwise indicated. PV is portal vein.

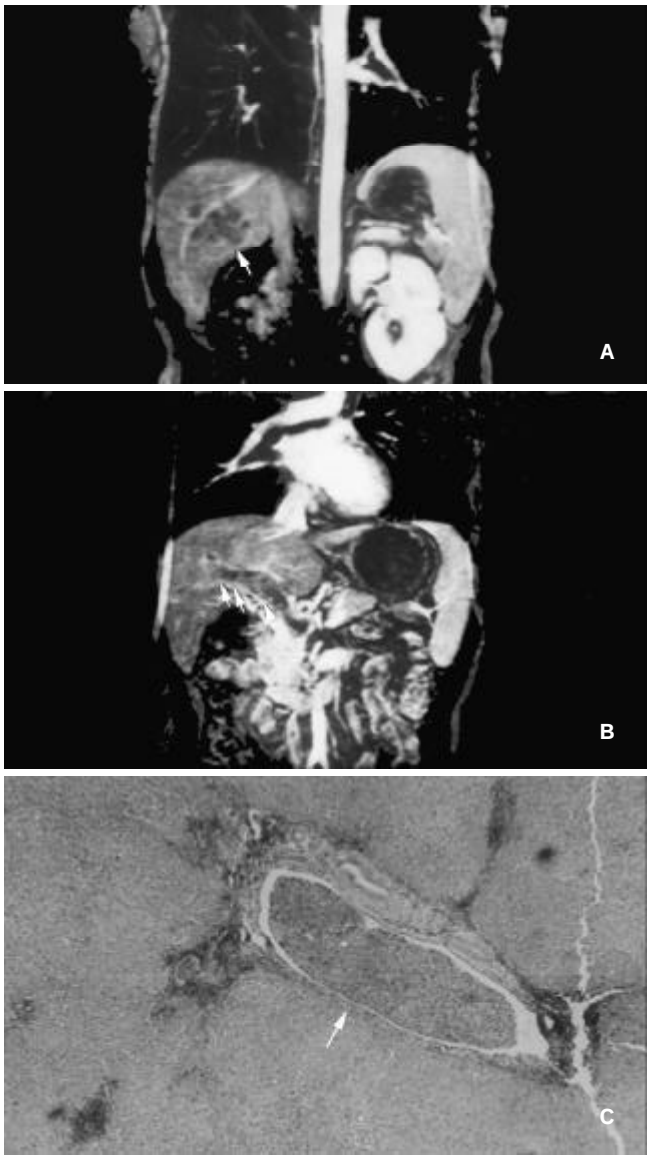

Figure 1 A patient with hepatocellular carcinoma in the right lobe. (A) Source image of 3-dimensional contrast-enhanced MR angiography demonstrates a hypointense tumor in the right lobe (arrow). (B) Multiplanar reconstruction of 3-dimensional contrast-enhanced MR angiography shows widened main and right portal vein with filling defects (arrow). (C) The patient underwent tumor resection and removal of tumor thrombi in the portal vein. Histopathology (HE ×40) reveals tumor thrombus in the portal vein (arrow).

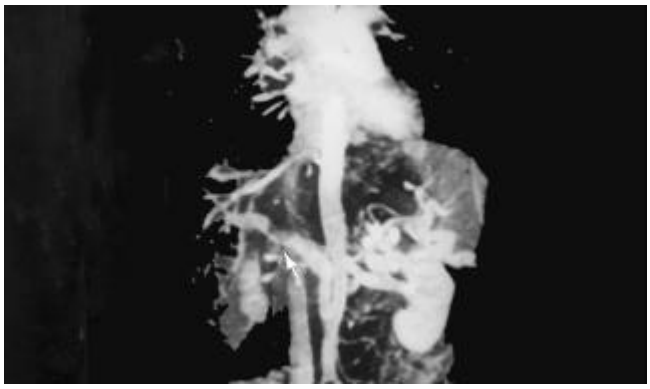

Figure 3 A patient with hepatocellular carcinoma in the left lobe. 3-dimensional contrast-enhanced MR angiography demonstrates occluded left portal vein and irregular filling defect in the main portal vein (arrow). The right portal vein is normal.

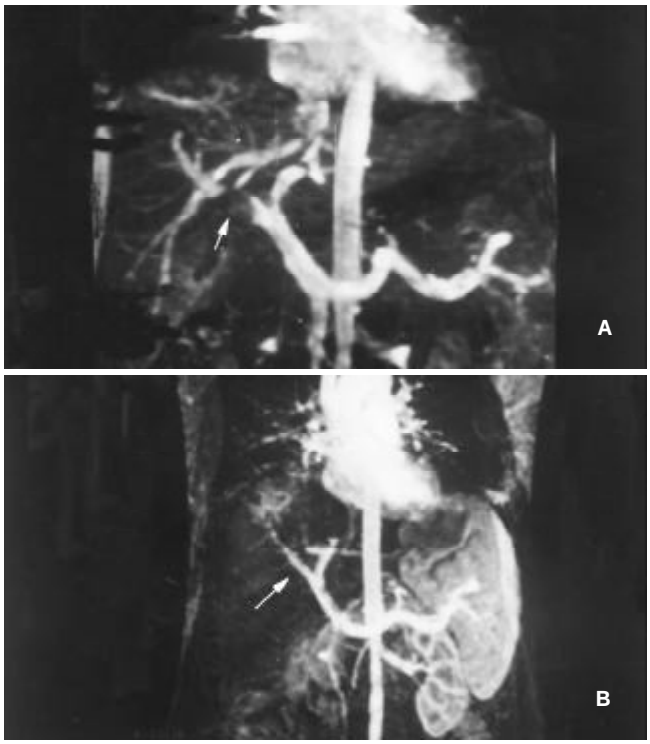

Figure 2 A patient with hepatocellular carcinoma in the right robe. (A) 3-dimensional contrast-enhanced MR angiography depicts a nodular filling defect in the right portal vein (arrow). (B) After partial right hepatic resection and removal of the tumor thrombi, the right portal vein is shown patent (arrow).

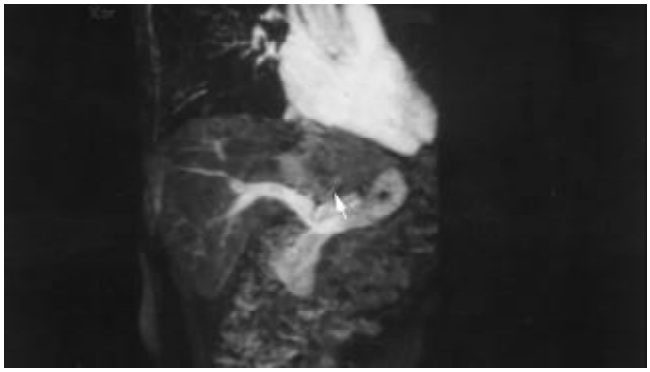

Figure 4 A patient with hepatocellualr carcinoma in the left lobe (arrow). The left portal vein is not visualized and interpreted as occlusion. At surgery, however, it was only compressed by the tumor.

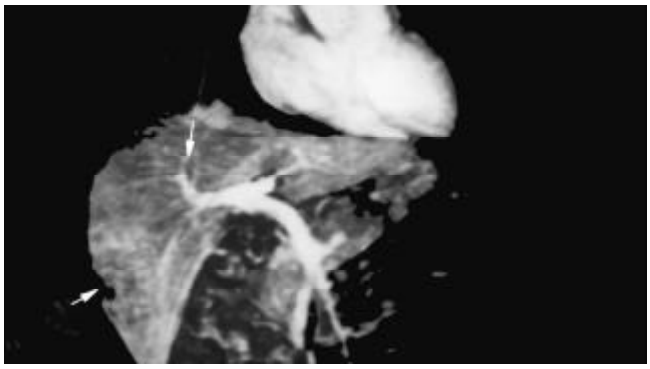

Figure 5 A patient with hepatocellular carcinoma in the right lobe (thick arrow). The normal right anterior portal vein (thin arrow) is misinterpreted as the right portal vein. But at surgery, the right posterior portal vein was involved by the tumor.

DISCUSSION

Hepatocellular carcinoma often invades the portal venous system[22]. Once this system is involved, the prognosis and quality of life of the patients become extremely poor as a result of increased portal pressure, intrahepatic spread of the tumor, and deteriorated liver function[22-24]. Traditionally, involvement of the main PV or the bifurcation of the PV is the indications of the unresectability. However, with the advances in surgical technique for hepatic resection, the survival of these patients can be prolonged by combination of hepatic resection, removal of tumor thrombi in the PV and post-operative transarterial embolization[23]. The removal of tumor thrombi in the main PV can relieve portal hypertension, lower the risk of variceal bleeding and partially restore the liver function. Accordingly, prior to the appropriate surgical or interventional planning to be made, it is crucial to determine whether the portal venous system is patent or invaded and the site and the extent of the invasion.

In our results, 3D CE MRA was 98 % sensitive and 99 % specific in the diagnosis of the involvement of the main PV and its intrahepatic branches. The accuracy in depicting main PV involvement was 100 %. A minor compromise of positive predictive value (96 %) of 3D CE MRA was due to the false positive diagnosis for evaluation of the left PV. However, for the main and right PV, the positive predictive value reached 100 %. Using a technique similar to ours, Kreft *et al*[25] reported a sensitivity and specificity of 100 % and 98 % for identifying PV thrombosis in 36 patients.

US is currently the screening technique for the PV. Tessler *et al*[26] evaluated the main PV with color Doppler US in 215 patients and showed 9 of them with PV thrombosis. The sensitivity was 89 %, specificity was 92 %, negative predictive value was 98 %, and positive predictive value was 62 %. Bach *et al*[27] found that color Doppler US had a sensitivity of 93 %, specificity of 99 %, positive predictive value of 97 % and negative predictive value of 98 % for evaluation of the main, left and right PV in 63 patients with hepatic tumors. In a recent study by Marshall *et al*[28], microbubble contrast-enhanced color Doppler US was used to improve the visualization of the PV, but the accuracy was only 87 % for diagnosis of PV thrombosis in 15 patients. CT during arterial portography (CTAP) is also frequently employed to assess the portal venous system. According to Bach' s study[27], it gave a sensitivity of 90 %, specificity of 99 %, positive predictive value of 95 % and negative predictive value of 97 % for evaluation of the PV involvement. Compared with the findings using US or CTAP, our study showed that 3D CE MRA was more accurate in demonstration of the PV involvement by hepatic tumors, especially regarding its higher sensitivity. Although US is the first-choice imaging modality, it is observer dependent and sometimes hampered by patient' s habitus and presence of bowel gas, ascites and heterogenous cirrhotic liver. When venous flow in patent PV was slow or stagnant, a PV thrombosis might be misdiagnosed. Similarly, false negative results might occur when flow was detected in a collateral vein and it was erroneously thought to be a patent main PV, which was actually thrombosed[2,26-28]. Thus, 3D CE MRA should be a useful noninvasive alternative when the visualization of the PV on US was inadequate or when the involvement was suspected clinically but the US diagnosis was indeterminate. In comparison to CTAP, 3D CE MRA is readily acceptable by patients owing to its noninvasive nature, the lack of allergic reaction to iodine and the lack of radiation. With a higher sensitivity and equal specificity, 3D CE MRA can replace CTAP for evaluation of the PV.

Nevertheless, the two false positive results of 3D CE MRA in demonstration of the patency of the left PV indicate that the assessment of the left PV could be compromised by the presence of large masses in left lobes. These masses caused substantial compression of the left PV. When collapsed, the left PV was underfilled with contrast medium injected from a peripheral vein and hardly distinguishable from the surrounding enhanced tumor. Therefore, 3D CE MRA had limitation in distinguishing compression of the small-caliber left PV from occlusion by tumor, which might adversely affect the surgical or interventional treatment options.

As for one false negative diagnosis occurred on the right PV, an anatomic variation of the PV found at surgery was thought to be the reason. In that case, the main PV trifurcated directly into the left and right anterior and right posterior PV at the porta hepatis. Although the right posterior PV was invaded by tumor, the right anterior PV was normal. On 3D CE MRA, we erroneously interpreted the normal right anterior PV as the right PV. In studies by Atri and Akgul *et al*[29,30], variation of the intrahepatic PV branching was common and trifurcation of the main PV could occur in 10.8 % and 12.3 % of patients respectively. As a result, the images of 3D CE MRA must be interpreted meticulously, with an understanding of the vascular anatomy and variation, and also with attention to the other potential sources of error noted above.

In summary, 3D CE MRA is an excellent noninvasive alternative to US for imaging the portal venous system. It is highly accurate in the evaluation of the PV involvement by hepatic tumors and is able to provide valuable information before surgery and interventional treatment for liver tumors.

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