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Submillimeter-pixel MR Images of Hepatic Cavernous Hemangiomas

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Several criteria have been used for differentiating hepatic cavernous hemangioma from other tumors at magnetic resonance imaging (MRI). Included are signal intensity and lobulation of the tumor. We counted the frequency of presence of lobulation of liver hemangiomas on T_2-weighted images (T2WI), and measured the signal-intensity ratio (SIR) on T_1-weighted images (T1WI) and on T2WI with a 0.9 mm × 0.9 mm pixel size using a 0.5 T magnetic resonance system.

Eighty-three cavernous hemangiomas in 44 patients and 67 malignant tumors in 44 patients were retrospectively studied. Seventy-five of the cavernous hemangiomas (90%) exhibited lobules of various sizes, and four of the malignant tumors (6%) exhibited lobulations. The cavernous hemangiomas had a significantly higher SIR than the malignant tumors on T2WI: 3.0 ± 0.7 and 1.9 ± 0.8 ($p < 0.001$), respectively.

The presence of lobulation together with a high SIR was a useful measure for differentiating cavernous hemangiomas from other liver tumors.

Key words: cavernous hemangioma of liver, MRI

Introduction

A HIGH SIGNAL INTENSITY of hepatic cavernous hemangioma on a T_2-weighted image (T2WI) facilitates its differentiation from other malignant tumors.[1–4] Small cavernous hemangiomas, especially those smaller than 2 cm in diameter, do not always have a high signal intensity due to a partial volume effect,[2] and make the diagnosis difficult.[5–7] Images with a small pixel size and thin slice are expected to delineate architectures of the hemangioma as well as to reduce the partial volume effect. We studied the structure and signal-intensity ratio (SIR) of cavernous hemangiomas and malignant liver tumors by using images with a pixel size of 0.9 mm×0.9 mm and a 7-mm slice thickness.

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Materials and Methods

Eighty-three cavernous hemangiomas were studied in 44 patients (24 men and 20 women, age range: 32 to 82 years, average age: 53 ± 10 years old [1SD]) during the period from February 1992 to October 1993. One patient had six cavernous hemangiomas, four patients had four, six patients had three, ten patients had two, and the remaining 23 patients had a single cavernous hemangioma.

Contrast-enhancement studies were performed using Gd-DTPA in four patients. Computed tomography (CT) was performed in 32 patients, and a combination of CT and angiography in five patients. In three patients, magnetic resonance imaging (MRI) was performed twice at an interval of at least one year. The data obtained in the second MRI examination were excluded from the present study.

Sixty-seven malignant tumors were studied in 44 patients (30 men and 14 women, age range: 33 to 79 years, average age: 61 ± 10 years old) during the period from February 1992 to September 1995. There were 33 hepatocellular carcinomas (HCC) in 26 patients. There were 34 metastatic liver tumors in 18 patients, 15 metastases in six patients from stomach cancer, eight

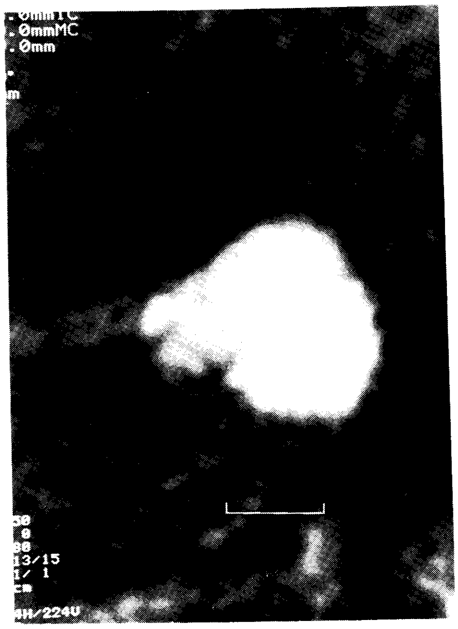


Fig. 1. T_2-weighted magnified image of a cavernous hemangioma in a 62-year-old female patient. The tumor consists of lobules. The bar indicates 1 cm.

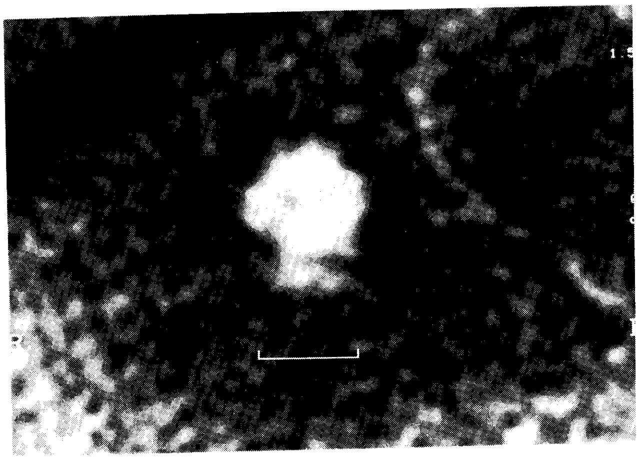


Fig. 2. T_2-weighted magnified image of a cavernous hemangioma in a 59-year-old male patient. This small hemangioma was found incidentally at US. The bar indicates 1 cm.

metastases in three patients from ovarian cancer, and six metastases in three patients from colon cancer. The remaining five tumors consisted of two direct invasions from a gall-bladder cancer and from a cholangiocarcinoma, one metastasis from a kidney cancer, one metastasis from a cecal carcinoid, and one metastasis from an unknown origin.

Among the 26 patients with HCC, two patients had already taken a transarterial tumor embolization at the time of MRI, and these tumors were excluded from the present study. None underwent tumor biopsy. Two of the six patients with metastases from stomach cancer and the remaining 12 patients underwent surgery, except for the one from an unknown origin. All 44 patients underwent ultrasound (US), CT, and celiac angiography.

All subjects assumed a supine position with an elastic band around the abdomen to reduce respiratory motion artifacts during MRI. A wireless axial pair resonator (WAPR) was used to enhance the signal intensity.[8,9] One of the WAPR coils was carefully placed over the patient and the other under the patient to sandwich the area of interest.

Axial T_1-weighted images (T1WI) were taken with the following acquisition parameters: repetition time [TR] 350 to 380 msec/echo time [TE] 16 to 20 msec, multi-section, single-echo, FOV 20 cm, matrix size 224 $\times$ 224, section thickness 7 mm, slice interval 1 mm, and four-signal averaging. Axial T2WIs were taken at the same location with the same acquisition parameters as those of T1WI, except for TR/TE 2000 msec/80 to 100 msec and two-signal averaging. The phase-encoding gradient was set in an anterior-to-posterior direction to reduce motion artifacts of the bowel. Respiratory compensation by means of reordering of the phase encoding steps was employed. Thirty to forty minutes were required to complete the procedure in one patient. All the images were acquired using a 0.5 T superconducting system (RESONA, Yokogawa Medical Systems Co., Tokyo).

Maximum dimension of the cavernous hemangioma on the axial image having the largest cross sectional area of a tumor was recorded as the tumor size. We divided the cavernous hemangiomas into three groups according to their sizes: group 1 included hemangiomas with a tumor size of 1.0 cm or less, group 2 with a tumor size greater than 1.0 cm and less than or equal to 2.0 cm, and group 3 with a tumor size greater than 2.0 cm. The malignant tumors were not classified by their size.

Presence of lobulation was visually determined on the T2WI. A positive lobulation was documented when the tumor had a lobulation greater than 0.3 cm in diameter on the tumor margin or when the tumor was composed of multiple lobules.

Signal intensities were measured on the monitor at the tumor and at the adjacent normal liver tissue using an operator-defined circular region of interest (ROI) which was about the short diameter of the tumor taken on the T1WI and T2WI. The signal-intensity ratio was obtained as the ratio between these two quantities. When a tumor had an inhomogeneous signal intensity, the ROI was taken to encircle the maximum or the minimum intensity area.

The signal-intensity ratios of the cavernous hem-

Table 1. Signal-intensity ratios of tumors

	T_1	T_2	number of cases of lobulation
hemangioma (n = 83)	0.75 ± 0.11 (0.51–0.97)	2.96 ± 0.67 (2.00–4.60)	75
HCC (n = 33)	0.94 ± 0.29 (0.41–1.83)	1.80 ± 0.40 (1.18–2.60)	3
stomach (n = 15)	0.84 ± 0.09 (0.64–0.98)	1.99 ± 1.01 (1.20–2.30)	0
ovary (n = 8)	0.65 ± 0.29 (0.35–1.21)	1.84 ± 0.52 (1.10–2.30)	0
colon (n = 6)	0.80 ± 0.08 (0.69–0.86)	1.66 ± 0.27 (1.40–2.00)	1
others (n = 5)	0.95 ± 0.29 (0.69–1.36)	2.01 ± 0.31 (1.62–2.30)	0

HCC indicates hepatocellular carcinoma. Stomach, ovary, and colon indicate the origin of cancers metastasizing to the liver. Others include one gall-bladder cancer, one cholangiocarcinoma, one carcinoid, and one renal cell cancer, with the remaining one being metastatic liver cancer from an unknown origin. Inside the parentheses are a number of cases for each case and a range of the signal-intensity ratio.

angiomas and the malignant tumors were compared using the Wilcoxon rank-sum test. The value of the SIR and the frequency of the lobulations among the different tumor-size groups were statistically analyzed using the Kruskal-Wallis test and a contingency table.

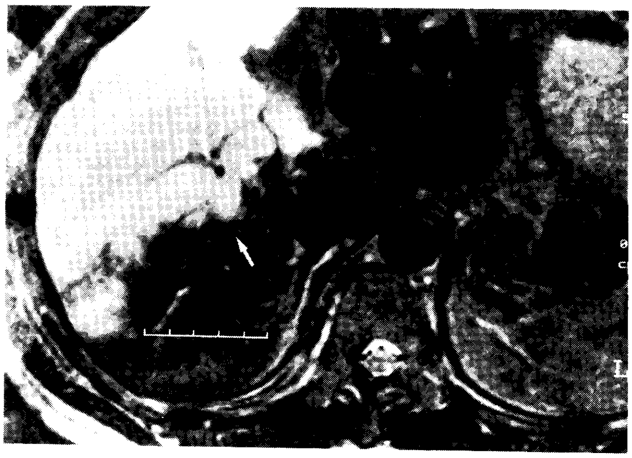
Results

All cavernous hemangiomas had a low signal intensity and an ill-defined margin on the T1WI. On the T2WI they had a high signal intensity and a well-defined margin against the surrounding liver tissue. Figures 1 through 3 depict typical hemangiomas on the T2WI.

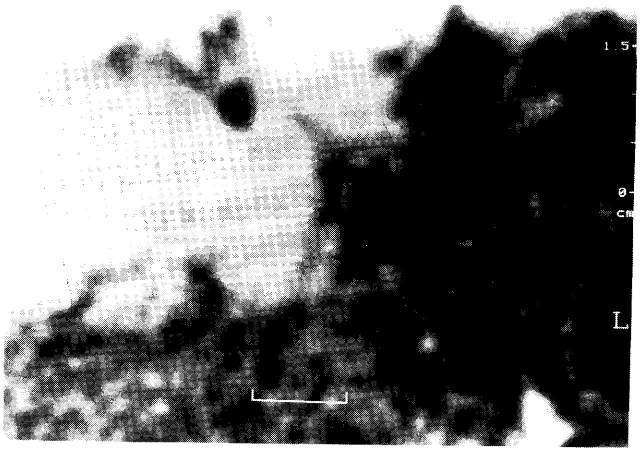
The hepatocellular carcinomas had a signal intensity varying from low to slightly high on the T1WI. Seven nodules had a low signal-intensity capsule around the tumor, and the remaining 26 nodules had an ill-defined margin. Figure 4 shows a giant HCC with lobulation.

The signal intensities of the metastatic tumors were low to slightly high on the T1WI (Table 1). Those on the T2WI were uniformly higher than the surrounding liver tissue. The metastatic tumors sometimes exhibited one or more areas with low signal intensity on the T1WI and high signal intensity on the T2WI (Fig. 5).

The cavernous hemangiomas had diameters ranging from 0.5 cm to 15 cm (average 2.0 ± 1.5 cm). There were 25 cavernous hemangiomas in group 1, with an average diameter of 0.8 ± 0.2 cm. There were 31 hemangiomas in group 2, with an average diameter of 1.6 ± 0.3 cm. There were 27 hemangiomas in group 3, with an average diameter of 3.5 ± 1.8 cm. The malignant tumors had diameters ranging from 0.5 cm to 15 cm (average 3.0 ± 2.5 cm).



a



b

Fig. 3. T_2-weighted image of a large cavernous hemangioma in a 59-year-old male patient. (a) A large tumor occupies almost half of the right lobe. On the dorsal side of the hemangioma, the tumor has a homogeneous, hyperintense signal with dense septa between the lobules. The interval between the ticks is 1 cm. (b) Magnified image of a portion in image A (*arrow*). The tumor margin is irregular and contoured by lobules of various sizes. The bar indicates 1 cm.

The cavernous hemangioma had lobulation of various size ranging from 0.3 cm to 3.0 cm. The hemangiomas greater than 2.0 cm exhibited lobulation at the margin (Fig. 3). The interposed septa between each lobule were 0.1 cm to 0.3 cm in thickness, which corresponded to a size of one to three pixels.

A total of 75 hemangiomas (90%) had lobulations (Table 2): 20 hemangiomas (80%) in group 1, 29 hemangiomas (94%) in group 2, and 26 hemangiomas (96%) in group 3. Three hemangiomas in group 1 and one hemangioma in group 3 had no lobulation. The presence of lobulation was equivocal for two hemangiomas each in groups 1 and 2. There was no significant difference in the manifestation of lobulation among the three groups (contingency table, $p > 0.1$). A

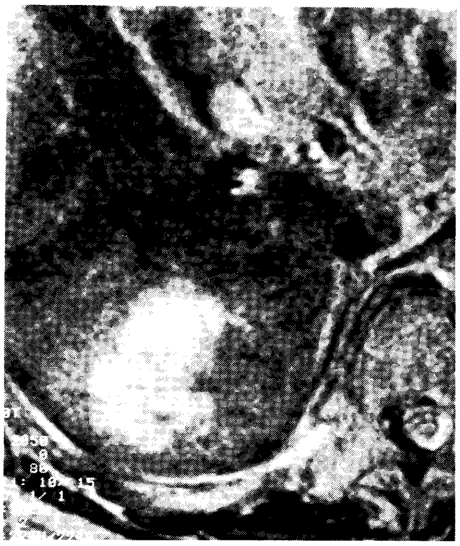


Fig. 4. A hepatocellular carcinoma in a 55-year-old male patient. He died of cancer two years after the MR study in spite of multiple transarterial tumor embolizations. The signal-intensity-ratios (SIR) were 0.8 and 1.9 on the T1WI and T2WI, respectively.

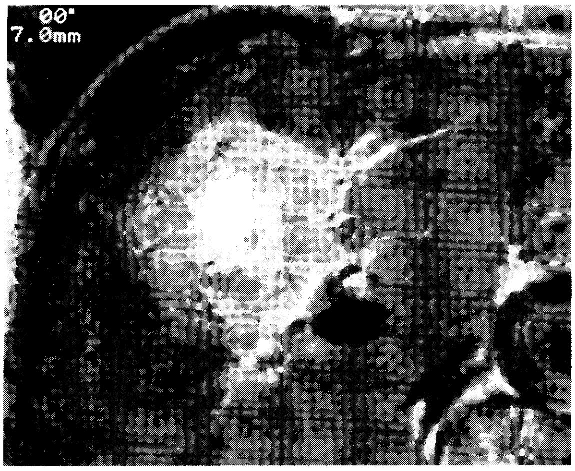


Fig. 5. A liver tumor metastasized from renal cell carcinoma in a 73-year-old male patient. The center of the tumor was low on the T1WI and high on the T2WI, suggesting the existence of tumor necrosis.

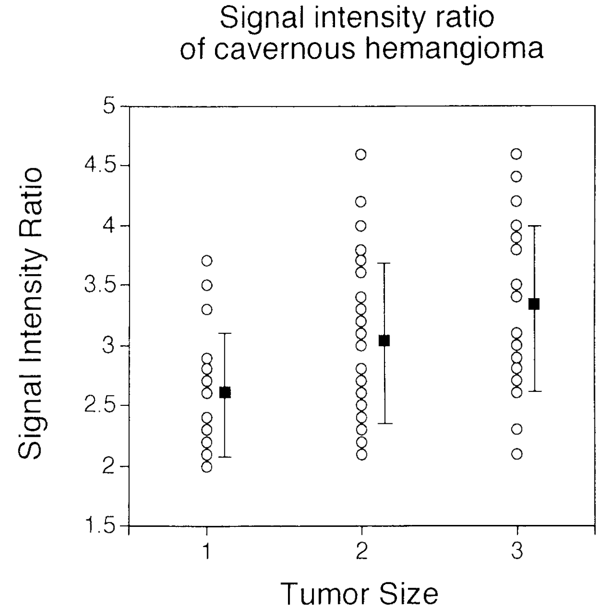


Fig. 6. Scatter plot of SIR for different sizes of cavernous hemangiomas. Closed squares indicate the averaged values with standard error bars.

Table 2 Lobulation of hepatic cavernous hemangioma with different sizes

lobulation	size group 1 ($r \leq 1.0$ cm)	group 2 (1.0 cm $< r \leq 2.0$ cm)	group 3 (2.0 cm $< r$)	total
+	20	29	26	75
±	2	2	0	4
–	3	0	1	4
total	25	31	27	83

r is the longer diameter of hemangioma. +, ±, and – show that the lobulation is respectively definite, equivocal, or negative on the T_2-weighted image.

total of four malignant tumors (6%) exhibited lobulations: three out of 33 HCC (9%) and one out of six metastatic tumors from colon cancers (17%).

The average SIR of the cavernous hemangiomas was 0.8 ± 0.1 (range, 0.5 to 1.0) on the T1WI, and that of the malignant tumors was 0.9 ± 0.1 (range, 0.4 to 1.8). Those on the T2WI were 3.0 ± 0.7 (range, 2.0 to 4.6) and 1.9 ± 0.8 (range, 1.1 to 2.6), respectively. There was a significant difference in the SIR between the cavernous hemangiomas and the malignant tumors on the T2WI ($p < 0.001$), but no statistical difference on the T1WI ($p > 0.1$).

The respective SIR for the hemangiomas in group 1, in group 2, and in group 3 were 2.6 ± 0.5, 3.0 ± 0.6, and 3.3 ± 0.7 on the T2WI (Fig. 6). There was a significant difference in the SIR among the different groups (Kruskal-Wallis test, $p = 0.004$). There was no significant difference in the SIR among the groups on the T1WI.

Discussion

Hepatic cavernous hemangioma is a common benign tumor of the liver. Small hemangiomas are often disregarded by surgeons or pathologists due to their generally benign nature. The clinical significance of cavernous hemangiomas arises from their confusion with other liver tumors, particularly when patients have known or suspected malignancy.

In the present study, the cavernous hemangiomas were initially found at US or found incidentally at MR. These cavernous hemangiomas were studied periodically by US every two to six months over spans of time ranging from 18 to 48 months. None of the cavernous hemangiomas changed in size during the observation period. Five small hemangiomas in group 1 were not delineated at CT. The remaining 78 hemangiomas were suggestive of cavernous hemangioma at CT, but were not definitive.

The diagnosis of cavernous hemangioma can be confidently suggested if a follow-up imaging study demonstrates no change in size,[10] particularly for those lesions less than 4.0 cm in diameter. The diagnosis of the hemangiomas in the present study was based mainly on their invariable size during the observation intervals. None of the 83 cavernous hemangiomas was observed to enlarge over the period of 18 months to 48 months using US. These 83 tumors were thus believed to be cavernous hemangiomas, although none of the hepatic cavernous hemangiomas has been pathologically proven.

Hepatocellular carcinomas in 26 patients were diagnosed from patient histories: chronic hepatitis with or without liver cirrhosis and high serum concentration of hepatitis B or C antibody and of alpha-protein. Enhanced and nonenhanced CT and celiac angiography also supported the diagnosis.

Stomach cancers in six patients were diagnosed by an endoscopic biopsy. Four patients had liver tumors when the stomach cancers were diagnosed. These tumors were concluded to be metastases because of their rapid growth. The other two patients were found to have metastatic liver tumors after six and 12 months following surgery.

One of the main criteria for diagnosis of hepatic cavernous hemangioma[1,2] is hyperintensity of the tumor signal relative to normal liver on T2WI. In the present study, small cavernous hemangiomas tended to have a small SIR on the T2WI (Fig. 6). Itoh *et al*,[2] attributed the low SIR of small hemangiomas to the partial volume effect. Small tumors were more susceptible to the partial volume effect than large ones. Although the average SIR value of the malignant tumors was smaller than those of the cavernous hemangiomas in group 1, 21 of 67 malignant tumors (31%) had an SIR greater than or equal to the minimum SIR of the hemangioma. There was a considerable overlap in the SIR between the hemangiomas and the malignant tumors. Therefore, it would be difficult to diagnose a hemangioma on the basis of the SIR alone, specifically those smaller than 1.0 cm.

A cavernous hemangioma has a low signal intensity on nonenhanced T1WI. It demonstrates peripheral enhancement accompanied by a progressive and granular centripetally enhancing front after administration of a contrast medium.[11,12] It exhibits finally a uniform enhancement or a peripheral nodular enhancement with persistent central hypointensity.[13] These filling-in patterns imply that the contrast medium fills the cavernous space from the periphery to the center of the tumor, which is composed of small compartments or lobules connected by capillary networks.[14] Images with a higher resolution or with a higher sensitivity would reveal these filling-in patterns *in vivo*; in the present study, however, we could not achieve a signal-to-noise ratio high enough to delineate these process.

Various authors[7,13,15] report that cavernous hemangiomas show confluent locules or nodules of various sizes at MR using pixel sizes of from 3.2 mm × 1.6 mm to 1.3 mm × 1.3 mm with 10-mm to 15-mm slice thickness. Ros *et al*,[7] report frequent inhomogeneity on T2WI due to dense fibrosis and calcification. They attribute the homogeneous appearances to the lack of spatial resolution of MR units. Although we did not perform a comparative study using a small and large pixel-size image in the present study, thin-slice images with a small pixel size can be expected to reduce the partial volume effect and to depict the internal structures more clearly than thick-slice images with a large pixel-size.

A large portion of the cavernous hemangiomas demonstrated lobulation on the T2WI with a submillimeter-pixel, whereas a small fraction of malignant tumors exhibited lobulation. The presence of lobulation might be added to the signs used in the MR diagnosis of cavernous hemangioma, namely hyperintensity, sharp margins, and peripheral location.

Other metastatic tumors are said to have appearances similar to cavernous hemangiomas at MR, including pheochromocytomas, islet cell tumors, pancreatic adenocarcinomas,[16] and colorectal tumors.[17] The presence of lobules on T2WI of a hepatic tumor could be a useful adjunct in diagnosing hepatic cavernous hemangiomas, but follow-up study is indispensable and differentiation from other malignant tumors is absolutely necessary and essential.

Acknowledgments

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