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Comparison of Visualization of the Intrahepatic Portal Venous System by Two-Dimensional Time-of-Flight MR Angiography among Different Imaging Planes

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The differences in visualization of the intrahepatic portal system among different imaging planes obtained by two-dimensional (2D)-time-of-flight (TOF) magnetic resonance angiography (MRA) was examined comparatively. Ten healthy volunteers were subjected to 2D-TOF-MRA of the entire liver from three directions — sagittal, transverse and coronal — during breath-holding using 2D-fast low angle shot sequences. Using the obtained consecutive image data, MRA was reconstructed by the maximum intensity projection algorithm. MRA was observed in a cine mode display, and visualization of each portal branch was classified into 3 groups: A, B and C (excellent, fair and poor, respectively). The visualization rate from the portal vein trunk to the segmental branches in the right lobe excluding the right anterior superior branch was highest on the sagittal section. The visualization rate of each branch in the left lobe was low as a whole on images taken from the 3 directions; a particularly low rate was found on the transverse images so all of these cases were classified into Group C. In conclusion, for visualizing from the portal vein trunk to the branches in the right hepatic lobe as a whole, the sagittal section was good, but visualization of branches in the left lobe was poor in all sections. Therefore, visualization of the entire intrahepatic portal system by the ordinary 2D-TOF technique appears to have limits.

Key words: liver; MR angiography; MR imaging; portal vein

For MR imaging of the portal venous system, the two-dimensional (2D)-time-of-flight (TOF) technique has currently been used (Gullberg et al., 1987; Edelman et al., 1989a, 1989b). Although this technique is used in the evaluation of the extrahepatic portal system such as the esophageal varix (Finn et al., 1991), it has not been used for evaluation of the intrahepatic portal system because of its low spacial resolution. Ordinarily, a magnetic resonance angiogram (MRA) is reconstructed from the image data of the transverse section (Gullberg et al., 1987; Edelman et al., 1989a, 1989b). However, since the difference in visualization among the imaging sections of the intrahepatic portal system has never been examined by research, the optimum section plane is not yet known. In this study, the differences in visualization of the intrahepatic portal system among imaging sections by the 2D-TOF technique was examined comparatively.

Subjects and Methods

The subjects were 10 healthy adult volunteers aged 30-40 years (mean: 36 years). Prior to the start of each study, informed consent was obtained from each subject.

Abbreviations: 2D, two-dimensional; FA, flip angle; FLASH, fast low angle shot; FOV, field of view; Gd-DTPA, gadopentetate dimeglumine; GMN, gradient motion nulling; MIP, maximum intensity projection algorithm; MRA, magnetic resonance angiography; TE, echo time; TOF, time-of-flight; TR, repetition time.

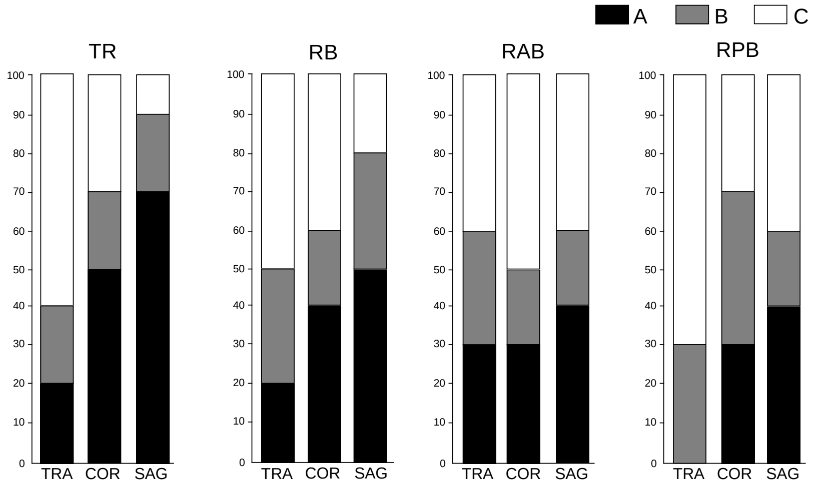

Fig. 1. Visualization rate of the portal vein trunk (TR), right branch (RB), right anterior branch (RAB) and right posterior branch (RPB). Group A (excellent): the entire length of blood vessel from the branch is continuously identifiable. Group B (fair): the blood vessel is identifiable but not continuously. Group C (poor): the blood vessel cannot be identified. COR, coronal plane; SAG, sagittal plane: TRA, transaxial plane.

MRA

A Magnetom H15 (Siemens, Erlangen, Germany) was used and a body coil was used as an imaging coil. For imaging sequences, a 2D-fast low angle shot (FLASH) (Haase et al., 1986) which had a gradient motion nulling (GMN) function (Haacke and Lenz, 1987; Laub and Kaiser, 1988) for the slice selection gradient and read-out gradient was used. Multiple imagings of the entire liver were performed on the sagittal, transverse and coronal sections during breath-holding. The MRA was reconstructed from obtained image data by the maximum-intensity projection (MIP) algorithm (Laub, 1990). A series of projection images were generated with viewing angles of -45˚ to +45˚ from the coronal plane at fixed 5˚ intervals. The parameters of imaging were as follows: repetition time (TR), 20 ms; echo time (TE), 8 ms; flip angle (FA), 40˚; field of view (FOV), 350×350 mm; matrix, 128×256; slice thickness, 4 mm; overlap, 2 mm; signal averaging, 1 (19 s, 5 multi-slice images).

Analysis of MRA

The blood vessels evaluated for this analysis were the portal vein trunk, right branch, left branch, right anterior branch, right posterior branch and each segmental branch (P2–P8). The MRA was observed in a cine mode display with the axis of head to tail rotation. Evaluation was based on the consensus of 3 trained radiologists. The visualization of each portal segment was classified into the following 3 groups: Group A (excellent), the entire length of blood vessel from the branch is continuously identifiable; Group B (fair), the blood vessel is identifiable but not continuously; and Group C (poor), the blood vessel cannot be identified.

Results

The percentage of each group is shown in Figs. 1–3, and the visualization rate is schematically depicted in Fig. 4.

In the vessels from the portal vein trunk to the right secondary branches, 40 to 70% of the subjects were classified as Group A on the image of the sagittal section. The percentage of Group A from the portal vein trunk to the right secondary branches was highest on the image of the sagittal section (Fig. 1). In the right segmental branches (P5–P7) excluding the right anterior superior branch (P8), 30 to 40% of the

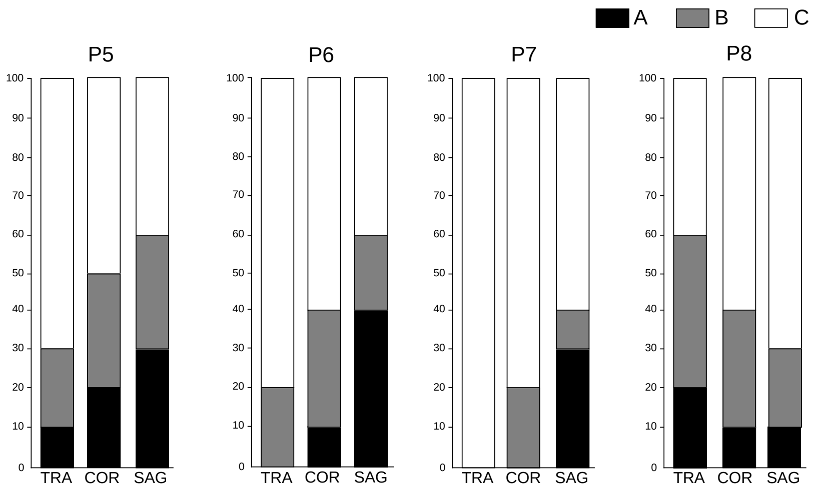

Fig. 2. Visualization rate of the portal branches in the right segment (P5—P8). Group A (excellent): the entire length of blood vessel from the branch is continuously identifiable. Group B (fair): the blood vessel is identifiable but not continuously. Group C (poor): the blood vessel cannot be identified. COR, coronal plane; SAG, sagittal plane: TRA, transaxial plane.

subjects were classified as Group A on the image of the sagittal section. The percentage from Group A of these branches was also highest on the image of the sagittal section. In P8, only 30% of the subjects were classified as Group A + Group B on the image of the sagittal section. However, 60% of the subjects were classified as Group A + Group B on the image of the transverse section (Fig. 2). The visualization rate of the left branch was low on images of all 3 directions. The rate was particularly low on images of the transverse section and every case was classified into Group C. The rate of the left regional branches (P2–P4) was also low as a whole. A particularly low rate was observed on images of the transverse and sagittal sec-

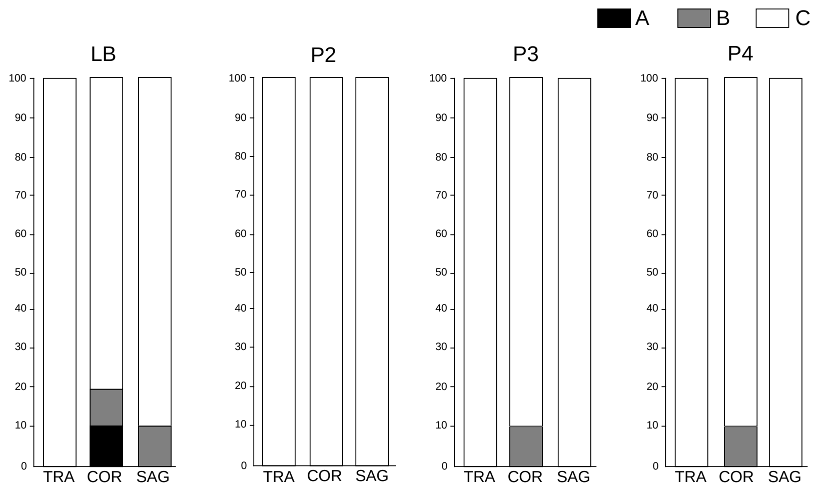

Fig. 3. Visualization rate of the portal left branch (LB) and branches in the left segment (P2–P4). Group A (excellent): the entire length of blood vessel from the branch is continuously identifiable. Group B (fair): the blood vessel is identifiable but not continuously. Group C (poor): the blood vessel cannot be identified. COR, coronal plane; SAG, sagittal plane; TRA, transaxial plane.

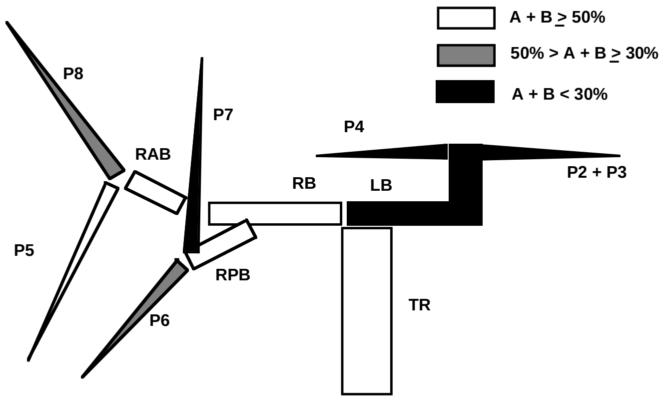

Fig. 4A. Map indicating the degree of visualization rate of each portal branch (coronal).

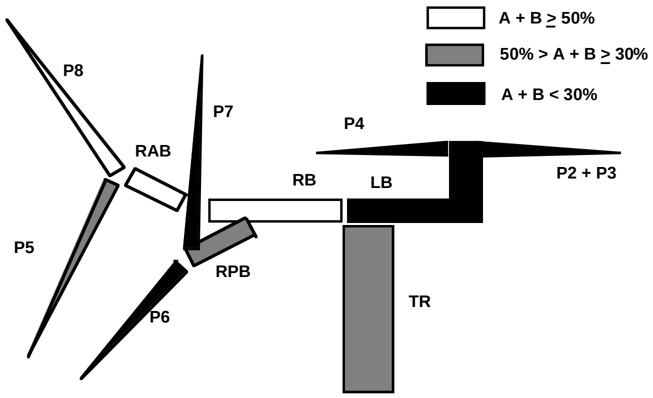

Fig. 4B. Map indicating the degree of visualization rate of each portal branch (transaxial).

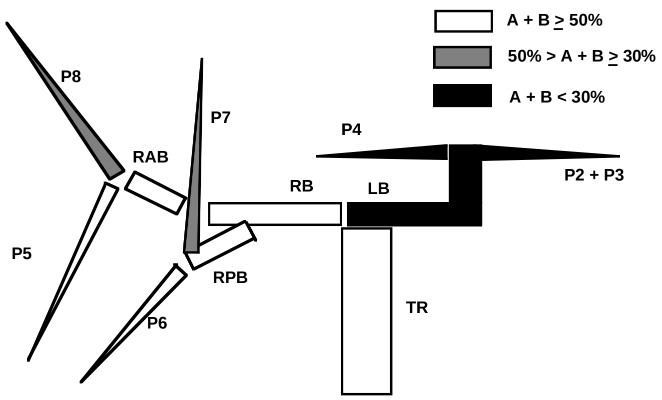

Fig. 4C. Map indicating the degree of visualization rate of each portal branch (sagittal).

tions and every case was classified into Group C (Fig. 3).

In summary, the sagittal section plane was best for visualizing from the portal vein trunk to the regional branches in the right lobe other than P8. However, the visualization rate of each branch in the left lobe was low as a whole on images of all 3 directions (Figs. 4 and 5).

Discussion

MRA of the abdominal region is performed mainly by the 2D-TOF technique (Gullberg et al., 1987; Edelman et al., 1989a, 1989b; Finn et al., 1991). This technique employs multiple repetitions of the 2D flow compensated gradient echo method by which imaging is performed in relatively short TR during breath-holding. Inflow enhancement produces a brighter signal for blood relative to the repeatedly excited stationary tissues which have a low signal (Edelman, 1993). When the flow compensation technique is applied, the phase shift that would normally result in subsequent dephasing and signal loss are minimized (Haacke and Lenz, 1987; Laub and Kaiser, 1988; Suto et al., 1994a). Signals of blood vessels on 2D-TOF depend on the flow rate and geometrical distribution of blood vessels (Marchal et al., 1990). Therefore, signal intensity is affected by the direction of blood vessels to the plane of the imaging section. When a blood vessel is vertical to the section plane of imaging, the inflow enhancement is the largest. When a blood vessel is running diagonally to the slice or present in the slice plane, the flowing spin receives multiple radiofrequency pulses and tends to be saturated (Lewin, 1992; Edelman, 1993). Consequently, signal intensity inside the blood vessel decreases and visualization of the blood vessel becomes incomplete.

In order to depict blood vessels clearly, it is fundamental to set the imaging section plane so that more components of vertical blood flow and less components of parallel blood flow to the slice section are included. The present study shows that the visualization rate from the portal vein trunk to the right segmental branches other than P8 was highest on the image of the sagittal section. The reason for this appears to be that blood vessels running vertically to the slice section were more in the saggital section than in other sections. Since P8 runs diagonally forward and upward in many cases, the visual-

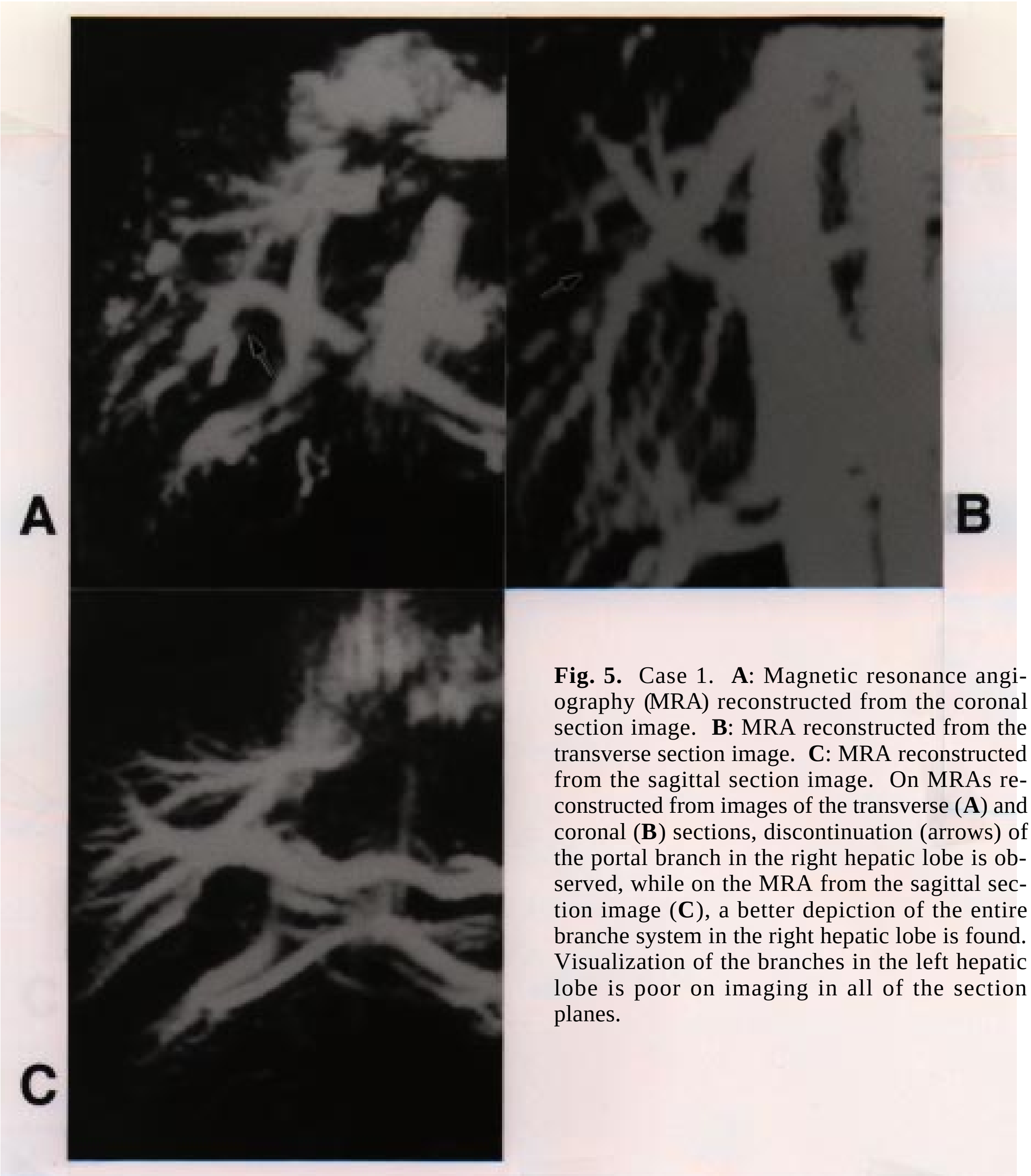

Fig. 5. Case 1. **A**: Magnetic resonance angiography (MRA) reconstructed from the coronal section image. **B**: MRA reconstructed from the transverse section image. **C**: MRA reconstructed from the sagittal section image. On MRAs reconstructed from images of the transverse (**A**) and coronal (**B**) sections, discontinuation (arrows) of the portal branch in the right hepatic lobe is observed, while on the MRA from the sagittal section image (**C**), a better depiction of the entire branche system in the right hepatic lobe is found. Visualization of the branches in the left hepatic lobe is poor on imaging in all of the section planes.

ization rate seems to be higher on images of the transverse section, as demonstrated in the present study. Although the sagittal section is better relatively, even in the portal trunk region where the diameter is large, the rate of the sum of Groups A and B did not reach 100%, indicating a low visualization rate of blood vessels. As for the cause of low visualization of the entire intrahepatic portal venous system by the 2D-TOF technique, factors other than the imaging section plane should be considered. The biggest problem in the application of the 2D-TOF technique to the abdominal region is the decrease in spacial resolution due to a stair-shape change of the blood vessel margin or discontinuation of blood vessels on an MRA reconstructed by the MIP method caused by phase discrepancy among images attributable to frequent breath-holdings (Bosmans et al., 1992; Suto et al., 1994a). Therefore, it is necessary to sufficiently explain to the subjects that breath-holding should be done consistently, with the same amount and speed of air intake for each breath interval. However, even the problem of breathing inconsistency cannot be completely at fault since there is another explanation for phase discrepancy: the voxel size in the 2D method is larger than that in the three-dimensional one (Bosmans et al., 1992; Lewin, 1992; Suto et al., 1994a), and a decrease in signal intensity due to phase dispersion caused by flow tends to occur, and eventually, cases of false positive in the diagnosis of intrahepatic portal obstruction or stenosis will increase (Suto et al., 1994a).

In the present study, the visualization rate was low despite the fact that the diameter of the portal left branch was relatively thick. As for the reason, saturation due to increased blood flow component parallel to the slice section plane can be considered. Phase dispersion also tends to occur when the left branch runs in a curve. For identification of peripheral blood vessels, identification of the root blood vessels is a prerequisite. The low visualization rate of branches in the left region in the present study can be attributed to the low visualization rate of the portal left branch in the root. Also, draining blood vessels which are saturated upstream of the portal left branch and a component with low blood flow signal intensity are other factors which reduce the visualization rate of blood vessels.

We think that the selection of an optimum imaging section plane is most successful when the researcher can find a section plane on which continuous depiction from the upstream thick blood vessels to the periphery is possible. For that purpose, the sagittal section plane is good for visualizing from the portal trunk to the regional branches in the right lobe. However, even in healthy volunteers in this study, the visualization rate from the left branch to its peripheral branches was low. Hence, in patients with decreased hepatic circulation such as cirrhosis of the liver, the visualization rate of the portal veins by the 2D-TOF technique will be lower.

As for measures against this shortcoming, we are now performing three-dimensional imaging by bolus intravenous injection of gadopentetate dimeglumine (Gd-DTPA) (Weinmann et al., 1984; Niendorf et al., 1991) during a single breath-hold instead of using the 2D-TOF technique, and reconstructing an MRA from the image data. This technique improved visualization of the intrahepatic portal vein within a short time. Blood saturation is suppressed by the T1 shortening effect of the contrast agent. A decrease in the spacial resolution due to phase dispersion in respiration which occurred during the 2D-TOF technique can be avoided because of the three-dimensional data acquisition. In addition, the reduced number of breath-holds significantly increased patient comfort and tolerance of the MR examination. (Suto et al., 1994b, 1996).

In conclusion, the sagittal section plane is excellent for securing good visualization from the portal vein trunk to branches in the right hepatic lobe, but visualization of the left lobe branches is poor in the imaging of all the section planes. Therefore, the conventional 2D-TOF technique appears to have its limits for visualization of the entire intrahepatic portal venous system.

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