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Visibility of Epidermoid Tumors on Steady-State Free Precession Images

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PURPOSE: To determine whether steady-state free precession sequences improve the MR visibility of epidermoid tumors in comparison with spin-echo images. **METHODS:** Patients were four women and three men with epidermoid tumors in the subarachnoid spaces. MR was performed with a 1.5-T superconductive unit. For steady-state free precession imaging, three-dimensional Fourier transform fast imaging with steady-state free precession (FISP) images were used (20–40/7 [repetition time/echo time], flip angle of 25°). The visualization and contrast-to-noise ratio were compared in FISP images and spin-echo images. In one case, the images of FISP and fast low-angle shot were obtained with variable repetition times and flip angles to evaluate the best pulse sequences for the visualization of epidermoid tumors. **RESULTS:** The contrast-to-noise ratios between tumors and cerebrospinal fluid ranged from 7.9 to 17.5 (average was 12.9) on FISP images. The average of contrast-to-noise ratios on T1, T2, and proton density-weighted spin-echo images were 1.6, 2.0, and 4.2, respectively. Three-dimensional Fourier transform FISP images best showed central nervous system and demonstrated epidermoid tumors excellently. **CONCLUSIONS:** Epidermoid tumors in the subarachnoid spaces were better demonstrated on steady-state free precession (three-dimensional Fourier transform FISP) than on conventional spin-echo images.

Index terms: Epidermoid; Magnetic resonance, comparative studies; Brain, magnetic resonance; Brain, neoplasms

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Epidermoid tumors typically are shown by magnetic resonance (MR) imaging as slightly hyperintense to cerebrospinal fluid (CSF) on T1-, T2-, and proton density-weighted spin-echo images. However the difference of signals between epidermoid tumors and CSF is small, and frequently the exact extension of epidermoid tumors to the subarachnoid space is difficult on conventional spin-echo images. Gadopentetate dimeglumine is not useful because of poor enhancement of epidermoid tumors. Diffusion-weighted images may show epidermoid tumors with good contrast to CSF, but patient motion is a significant problem for applying this sequence. Except with intrathecal

infusion of contrast media, computed tomography (CT) cannot show epidermoid tumors well. To know the exact extension of epidermoid tumors before surgery, a more reliable method is required.

We have observed good visibility of epidermoid tumors using steady-state free precession images (three-dimensional Fourier transform fast imaging with steady-state free precession [FISP] images). In this report, 3-D Fourier transform FISP images are evaluated in comparison with spin-echo images for visualization of epidermoid tumors.

Materials and Methods

The patients were four women and three men with intracranial epidermoid tumors who ranged in age from 46 to 65 years. Histologic features and tumor extension were confirmed by surgery in all seven cases (Table 1).

MR was performed with a 1.5-T superconductive unit (Siemens Magnetom, Erlangen, Germany). In all cases, axial 2-D Fourier transform spin-echo images (T1-, T2-, and proton density-weighted images), and 3-D Fourier transform FISP images were obtained. Imaging param-

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TABLE 1: Clinical findings and locations of intracranial epidermoid tumors

Patient	Age	Sex	Symptoms	Location of tumor
1	59	F	Right abducent nerve palsy	Suprasellar cistern Right and left C-P angle
2	51	M	Left trigeminal neuralgia (V2, 3) Dysarthria Dysphagia	Prepontine cistern Suprasellar cistern Right and left C-P angle
3	55	F	Left trigeminal neuralgia (V2, 3) Left facial palsy	Prepontine cistern Right and left C-P angle
4	65	M	Right trigeminal neuralgia (V1, 2, 3)	Prepontine cistern Right C-P angle
5	46	F	Right trigeminal neuralgia (V3) Right hearing disturbance	Suprasellar cistern Right C-P angle
6	47	M	Right hearing disturbance	Prepontine cistern Right C-P angle
7	56	F	Left trigeminal neuralgia (V2, 3)	Left C-P angle

Note.—C-P angle indicates cerebellopontine angle.

ters of spin-echo images were 600/15 (repetition time [TR]/echo time) for T1-weighted image, 2300/90 for T2-weighted images, and 2300/22 for proton density-weighted images with a 192×256 matrix, 6-mm section thickness and 220-mm field of view. The 3-D Fourier transform FISP sequence applied in this study was supplied by Siemens for MR angiography, with velocity compensation gradients in the read and section-select directions. Imaging parameters of 3-D Fourier transform FISP images used in all seven cases were 20–40/7, 25° flip angle with a 192×256 matrix with 32 partitions and 220-mm field of view. The slab thickness for the 32 partitions was 50 mm. A presaturation pulse was not used.

Contrast-to-noise ratio between the tumor and CSF (C_{CSF}), and contrast-to-noise ratio between tumor and brain (C_{brain}) were obtained. These contrast-to-noise ratios were evaluated on FISP images and spin-echo (T1-, T2-, and proton density-weighted) images. C_{CSF} and C_{brain} were defined as follows: $C_{CSF} = ([SI \text{ of tumor}] - [SI \text{ of CSF}]) / \text{noise}$ and $C_{brain} = ([SI \text{ of tumor}] - [SI \text{ of brain}]) / \text{noise}$, where SI indicates signal intensity. The region of interest of CSF was set at the fourth ventricle. The region of interest of brain was set at the pons. The area of region of interest was 20 to 40 mm².

The visibility of tumors in the subarachnoid space was compared between 3-D Fourier transform FISP images and spin-echo (T1-, T2-, and proton density-weighted) images. These images were graded by three observers into three categories: (a) tumor was not seen or was only suspected by widening of the subarachnoid space (Grade I), (b) tumor was vaguely seen but not its exact extension to the subarachnoid space (Grade II), and (c) tumor was demarcated with clear margin (Grade III).

The single-section 2-D Fourier transform FISP and fast low-angle shot (FLASH) images of one case were obtained with variable TR (40, 80, 120) and flip angles (10°, 50°, 90°). The contrast-to-noise ratio of these images was evaluated for the most appropriate pulse sequence for the visualization of epidermoid tumors.

The resected specimen of one case was suspended in saline in a test tube and 3-D Fourier transform FISP and 2-D Fourier transform spin-echo images were obtained with the same pulse sequences as the MR images of the patients. Visibility of the epidermoid tumor in the test tube was evaluated.

Results

Comparison of Contrast between Spin-Echo Images and FISP Images

C_{CSF} on FISP image ranged from 7.9 to 17.5 (average C_{CSF} was 12.9). The average value of C_{CSF} on T1-weighted, T2-weighted, and proton density-weighted spin-echo images was 1.6, 2.0, and 4.2, respectively (Fig 1A). FISP images had best C_{CSF} , followed by proton density-weighted spin-echo images. T1-weighted and T2-weighted spin-echo images had poor contrast. C_{brain} on FISP images ranged from 0.1 to 6.2 (average contrast-to-noise ratio was 2.4). The average value of C_{brain} on T1-weighted, T2-weighted, and proton density-weighted spin-echo images was 15.5, 21.6, and 2.7, respectively (Fig 1B). T1-weighted and T2-weighted spin-echo images had better C_{brain} than FISP images.

Comparison of Visibility between Spin-Echo Images and FISP Images

The visibility of epidermoid tumors in the subarachnoid space was best on FISP images (Table 2). FISP images showed tumors in CSF with clear margins (Figs 2 and 3). Spin-echo images showed the tumors rather poorly. Demarcation of tumors from CSF was not clear on

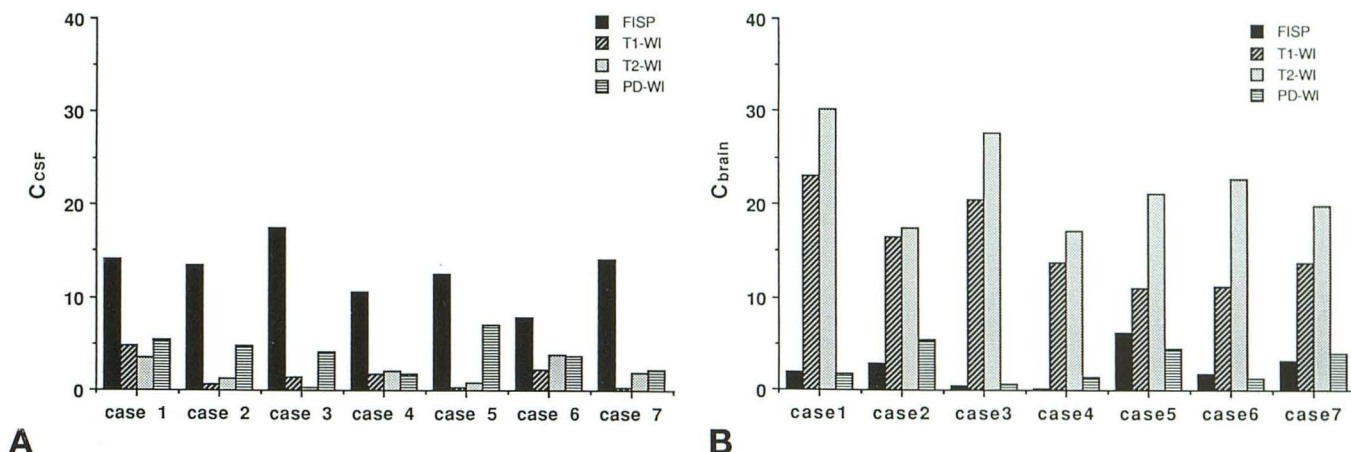


Fig 1. Contrast-to-noise ratio of seven cases on T1-, T2-, and proton density-weighted spin-echo images and FISP images.

A, Contrast-to-noise ratio between tumor and CSF (C_{CSF}). FISP images had best C_{CSF} on all the seven cases.

B, Contrast-to-noise ratio between tumor and brain (C_{brain}). T1- and T2-weighted spin-echo images had better C_{brain} than FISP images.

any type of spin-echo images. Tumors were not seen or were seen vaguely as a slightly hyperintense, inhomogeneous region on spin-echo images.

Changes of Contrast with Variable TR and Flip Angles on 2-D Fourier Transform FISP and FLASH

Small flip angle (10°) on FISP image did not demonstrate epidermoid tumors in CSF to good advantage. FISP images of shorter TR (40 milliseconds) and larger flip angles (50° and 90°) revealed better C_{CSF} (Fig 4A and C). FLASH images, which had poor C_{CSF} , did not show tumors clearly with any TR or flip angles (Fig 4B and D).

In Vitro Studies

The resected specimen suspended in a test tube filled with saline was imaged by 3-D Fou-

rier transform FISP and 2-D Fourier transform spin-echo images (Fig 5). T1- and T2-weighted spin-echo images did not clearly show the epidermoid tumor. Proton density-weighted spin-echo image and 3-D Fourier transform FISP image faintly showed the tumor with obscure margins. The good visibility of epidermoid tumors obtained with FISP images in vivo was not seen in the vitro study.

Discussion

Intracranial epidermoid tumors are usually located in the subarachnoid spaces including the cerebellopontine angle, suprasellar cistern, and parasellar region. The cerebellopontine angle is the most common site of occurrence of intracranial epidermoid tumors. When epidermoid tumors become large enough, they often extend along the subarachnoid spaces into the contralateral cerebellopontine angle, suprasellar cistern, and ambient cistern. The precise extension of tumors is important for the planning of surgery.

CT demonstrates epidermoid tumors as a mass of similar density to CSF (1), making the detection and delineation in the subarachnoid space difficult. Intratumoral calcification and marginal contrast enhancement may occur but are not frequently seen (2). Epidermoid tumors with high CT attenuation value have been reported but are rare (3, 4).

Since 1987, several authors have reported MR to be superior to CT in the visualization of

TABLE 2: Comparison of FISP and spin-echo images in showing epidermoid tumors

	FISP	Spin-echo (T1-weighted image)	Spin-echo (T2-weighted image)	Spin-echo (proton density- weighted image)
I	0	3	4	3
II	0	4	3	4
III	7	0	0	0

Note.—I indicates tumor not seen or only suspected by widening of subarachnoid space; II, tumor vaguely seen but not its exact extent in the subarachnoid space; and III, tumor demarcated with clear margin.

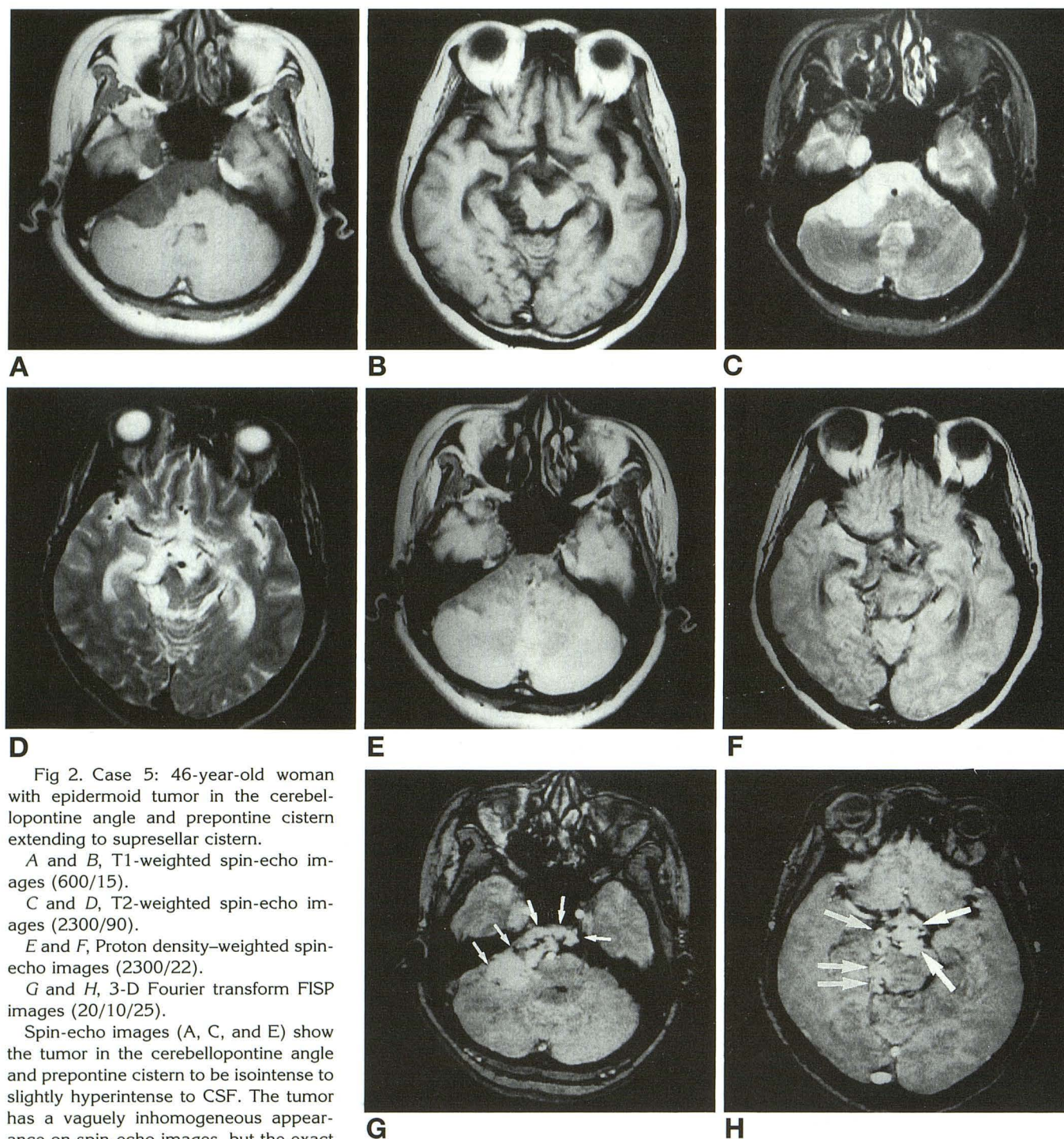


Fig 2. Case 5: 46-year-old woman with epidermoid tumor in the cerebellopontine angle and prepontine cistern extending to suprasellar cistern.

A and B, T1-weighted spin-echo images (600/15).

C and D, T2-weighted spin-echo images (2300/90).

E and F, Proton density-weighted spin-echo images (2300/22).

G and H, 3-D Fourier transform FISP images (20/10/25).

Spin-echo images (A, C, and E) show the tumor in the cerebellopontine angle and prepontine cistern to be isointense to slightly hyperintense to CSF. The tumor has a vaguely inhomogeneous appearance on spin-echo images, but the exact extensions in the subarachnoid spaces are not clear. The tumor in the suprasellar cistern is also difficult to recognize on spin-echo images (B, D, and F). FISP images show the tumor (arrows) with a clear margin against CSF (G and H).

epidermoid tumors (5–10). Typically, epidermoid tumors are demonstrated by MR as an isointense to slightly hyperintense mass, relative to CSF, with vaguely inhomogeneous appearance on all spin-echo pulse sequences. The demarcation of tumors from the surrounding

brain is good, because of much longer T1 and T2 values than those of the brain tissues. On proton density-weighted images thin rims of hyperintensity believed to be surrounding CSF may be seen (4). However in our study, a thin rim of hyperintensity was seen in only one of

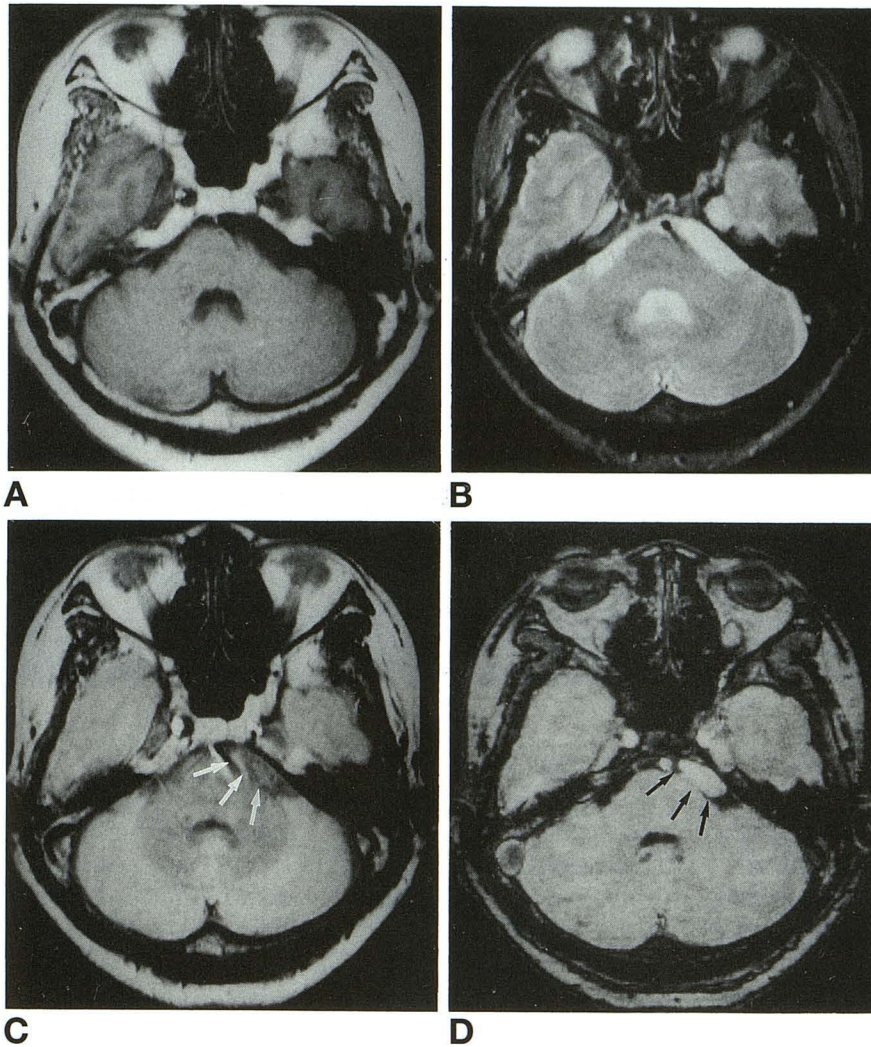


Fig 3. Case 7: A 56-year-old woman with epidermoid tumor in left cerebellopontine angle.

A, T1-weighted spin-echo image (600/15).

B, T2-weighted spin-echo image (2300/90).

C, Proton density-weighted spin-echo image (2300/22).

D, 3-D Fourier transform FISP image (20/10/25).

On T1- and T2-weighted spin-echo images, a slightly dilated subarachnoid space is seen at the left cerebellopontine angle, but the tumor is not identified (A, B). The proton density-weighted spin-echo image shows the tumor (arrows) to be slightly hyperintense against CSF (C). The FISP image clearly shows the tumor in the left cerebellopontine angle (arrowheads) with good contrast to CSF.

seven cases. The demarcation of tumors from CSF was not clear because of similar T1, T2, and proton-density values.

There are no other reports showing the usefulness of FISP or steady-state free precession images for depicting intracranial epidermoid tumors. In this study, FISP images clearly showed all the seven epidermoid tumors in the subarachnoid space with good contrast to CSF, but the demarcation of tumor from brain was not good. The contrast of the FISP depends on T1/T2 ratio, when TR is short enough compared with the T2. Proton density, T1, T2, and T2* also contribute to the contrast of FISP images. But our in vitro study cannot explain the better visibility of epidermoid tumors on FISP images. Epidermoid tumors were not depicted by T1-, T2-, or proton density-weighted, or even FISP images in vitro, indicating that the visibility of epidermoid tumors in vivo does not

depend on T1, T2, proton-density, or T2* values. There should be other factors to explain this phenomenon.

The original FISP, proposed by Oppelt (11), is very sensitive to field inhomogeneity that results in the unwanted signal variation (12). The conventional FISP applied in this study is made by modifying the gradient structure of original FISP to overcome this phenomenon. Haacke et al (12) mentioned that this modification of conventional FISP makes the signals sensitive to motion with resulting decrease in signal intensity for the moving tissue like CSF. The CSF surrounding epidermoid tumors is thought to be moving with turbulent motion that cannot be rephased even by velocity-compensated gradients, whereas protons composing the epidermoid tumors do not move freely. Therefore, the signal of epidermoid tumors is preserved as high intensity.

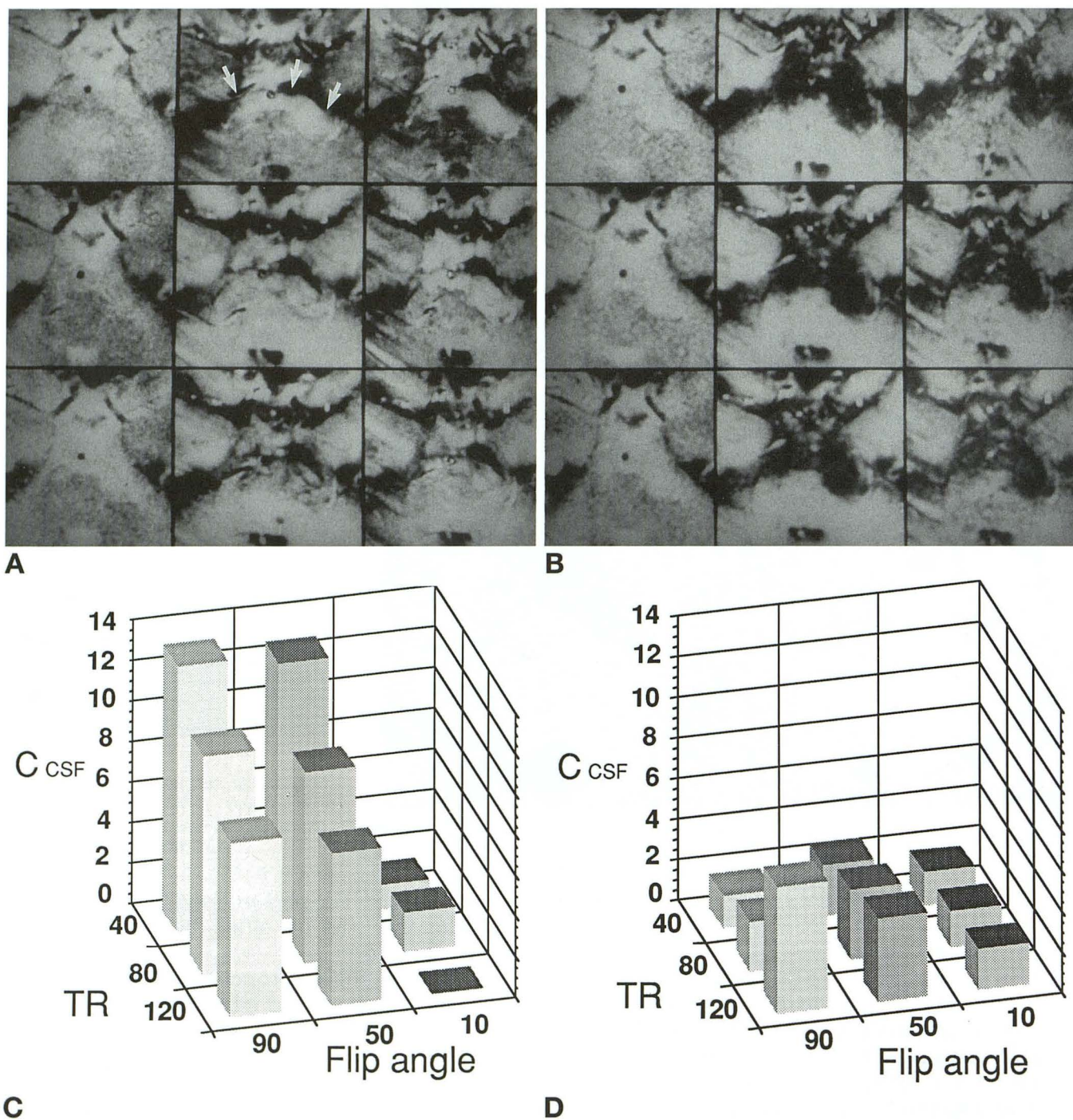


Fig 4. The change of contrast with variable TRs and flip angles on 2-D Fourier transform FISP and 2-D Fourier transform FLASH images.

A, 2-D Fourier transform FISP and B, 2-D Fourier transform FLASH images. In the top rows, TR is 40; in the middle rows, 80; and in the bottom rows, 120. In the left columns, flip angle is 10°; in the middle columns, 50°; and in the right columns, 90°.

The C_{CSF} s of C, 2-D Fourier transform FISP and D, 2-D Fourier transform FLASH. The epidermoid tumor is well seen with shorter TRs and moderate to large flip angles on FISP images (arrows). FLASH images do not show the tumor in the subarachnoid space with any combination of TR and flip angle.

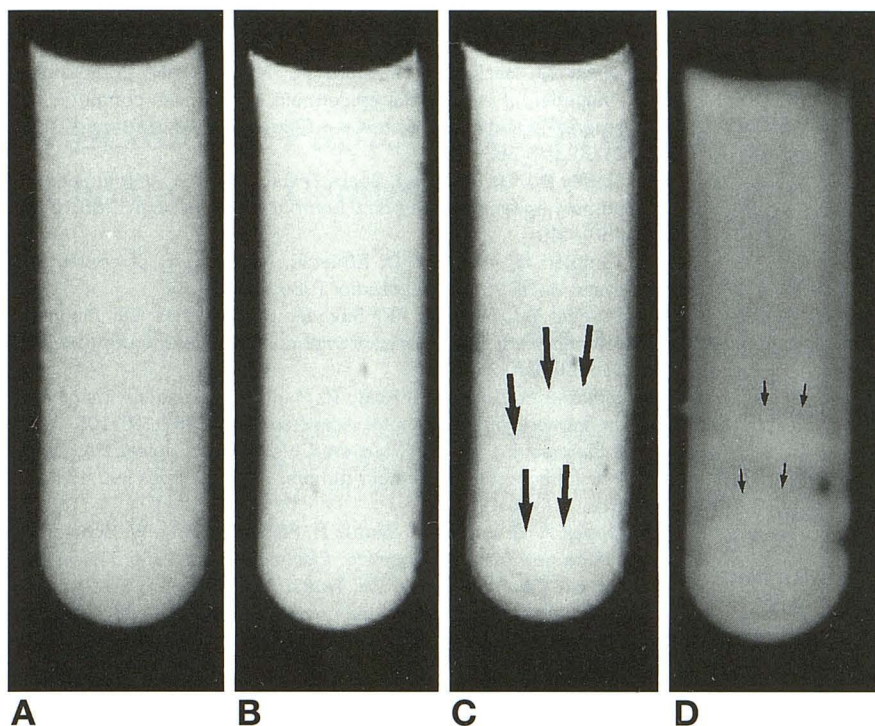


Fig 5. A, T1-weighted spin-echo image. B, T2-weighted spin-echo image. C, Proton density-weighted spin-echo image.

D, 3-D Fourier transform FISP image.

The resected specimen of an epidermoid tumor in a test tube is not seen on T1- and T2-weighted spin-echo images. Proton density-weighted spin-echo image and 3-D Fourier transform FISP image faintly show the tumor with obscure margins (arrows).

A similar report concerning the visualization of epidermoid tumors in CSF was offered by Tsuruda et al (13). This study showed the usefulness of diffusion-weighted MR imaging on differentiation between extraaxial cysts and epidermoid tumors, noting that CSF has an apparent diffusion coefficient twice that of soft tissue. The CSF in the subarachnoid space is moved by physiologic brain pulsations that elevates its apparent diffusion coefficient over stationary water by up to 400%. Therefore, the difference in the apparent diffusion coefficient between soft tissue and CSF may be significantly large. This effect of intravoxel incoherent motion causes a reduction of echo signal and therefore a reduction of signal intensity.

Diffusion-weighted MR imaging for the demonstration of epidermoid tumors is a good idea. However, in clinical practice, there is a major problem. Diffusion-weighted MR image often is spoiled by patient movement and pulsatile brain movement. On the other hand, a good-quality FISP image is easily obtained. FISP imaging also has a problem: CSF surrounding the brain surface or CSF in brain sulci sometimes shows hyperintensity similar to that of epidermoid tumors. This phenomenon is not very important for tumors in the prepontine cistern and cerebellopontine angle. So FISP image is thought to be more useful and more practical than diffusion-

weighted MR for demonstrating epidermoid tumors.

The C_{CSF} and C_{brain} are varied by the imaging parameters TR and flip angle on the FISP sequence. The image with shorter TR (TR less than 40 milliseconds) has good contrast for showing epidermoid tumors, explained by the effect of rewinder of the FISP sequence. If shorter TRs are applied, refocused transverse magnetization becomes the component of longitudinal magnetization by the next radio frequency pulse, resulting in the production of larger signals. The tissue, having long T2 relaxation time like epidermoid tumors, shows large signal by this rewinder effect of FISP.

The FISP image with flip angle of 10° did not show epidermoid tumors. The flip angle of more than 20° is required for the visualization of epidermoid tumors. But if larger flip angles (flip angle greater than 50°) are applied, the signal of CSF at brain surface also shows hyperintensity. This phenomenon makes the differentiation of epidermoid tumors from the CSF obscure. If a moderate flip angle is applied, the differentiation of tumors from CSF is better than with a larger flip angle.

Our recommended pulse sequence for the visualization of epidermoid tumors is 3-D Fourier transform FISP with a shorter TR (TR less than 40 milliseconds) and moderate flip angles

(20° to 50°). If the border of tumor and brain is not clear, additional FISP images of larger flip angles or spin-echo images should be obtained. 2-D Fourier transform FISP images with single section also show the epidermoid tumors well. However, 2-D Fourier transform FISP images with multisection techniques destroy the transverse magnetization resulting in the loss of the effect of rewinder on FISP sequence. In addition, low signal-to-noise ratio of 2-D Fourier transform FISP caused by short TR obscures the tumors. Therefore, a 3-D Fourier transform FISP technique that has better signal-to-noise ratio should be chosen.

In conclusion, a 3-D Fourier transform FISP sequence with shorter TRs (TR less than 40 milliseconds) and moderate flip angles (20° to 50°) was useful for showing epidermoid tumors in the subarachnoid spaces.

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