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H Mitsuoka, A Tsunoda, O Okuda, K Sato and J Makita

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Delineation of Small Nerves and Blood Vessels with Three-dimensional Fast Spin-Echo MR Imaging: Comparison of Presurgical and Surgical Findings in Patients with Hemifacial Spasm

Hideyuki Mitsuoka, Akira Tsunoda, Osamu Okuda, Kiyoshi Sato, and Junichi Makita

BACKGROUND AND PURPOSE: **We applied a 3D fast spin-echo (3D-FSE) MR imaging technique to the preoperative and postoperative evaluation of patients with hemifacial spasm.**

METHODS: **The study group comprised 20 patients. All images were acquired on a 1.5-T MR system with a 3D-FSE sequence.**

RESULTS: **In all 20 patients, the courses of the seventh and eighth cranial nerves were depicted separately, and the arteries presumed to be responsible for the hemifacial spasm were seen to be in contact with the facial nerves at the root exit zone (REZ). Eight patients underwent neurovascular decompression. In all patients, the presumed responsible blood vessels depicted by 3D-FSE MR imaging corresponded to intraoperative findings. In addition, postoperative 3D-FSE images confirmed the separation of the facial nerve from a contiguous vessel at the REZ.**

DISCUSSION: **The 3D-FSE technique makes it possible to obtain extremely high-quality images of microstructures in the cerebellopontine cistern, and it has several advantages over conventional angiography: it is noninvasive and able to depict the cranial nerves and surrounding vessels in the same image without contrast material, and it may be useful for postoperative evaluation of the decompression procedure. This imaging technique is expected to prove useful for the clinical evaluation of hemifacial spasm.**

Hemifacial spasm is characterized by unilateral, involuntary, paroxysmal, and repetitive spasm of the muscles innervated by the facial nerve. Generally, the spasm initially involves the eyelid on one side of the face, gradually extending to involve other regions on the same side. In most patients, symptoms are aggravated by fatigue, stress, or anxiety and continue even during sleep. In half the patients, symptoms are improved by lying on the unaffected side. There is no accompanying pain. Hemifacial spasm has been diagnosed on the basis of oculo-oral synkinesis on the blink reflex test, an electrophysiological examination (1–3), and by its pathognomonic clinical picture.

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From the Department of Neurosurgery, Juntendo University, Tokyo, Japan (H.M., A.T., O.O., K.S.); and Toshiba Medical Engineering Co, Tokyo, Japan (J.M.).

Address reprint requests to Hideyuki Mitsuoka, MD, Juntendo University School of Medicine, 1–1, Hongo 2-chome, Bunkyo-ku, Tokyo 113 Japan.

In general, medical management with carbamazepine (4), baclofen (5), and so on is the initial treatment of choice. If the patient does not respond to medical management or if severe complications develop, surgical treatment is considered. The neurovascular decompression method is now widely used (6). Conventionally, preoperative cerebral angiography has been performed to identify the blood vessel presumed to be responsible for the hemifacial spasm. According to the findings of a number of studies in which calculations were performed on cerebral angiographic images, the root exit zone (REZ) of the facial nerve is considered to be located 13.1 mm (SD, 1.6 mm) from the median line (7). However, this measurement approach has several problems. For example, the location of the REZ varies among patients, and, infrequently, hemifacial spasm may be caused by small tumors or vascular malformations that cannot be detected by cerebral angiography (8, 9). To identify positional variations in the location of the REZ, CT has been used in addition to cerebral angiography, despite the limitations of CT caused by bone artifacts in the posterior cranial fossa. MR imaging provides clinically useful studies, but small structures near the cerebellopontine angle cannot be satisfactorily visualized with conventional imaging methods. In particular, small blood vessels are poorly depicted, making it difficult for MR imaging to replace cerebral angiography.

The 3D fast spin-echo (3D-FSE) method has become clinically available as a result of recent technological advances in MR imaging; in particular, the development of high-speed data processing, which makes it possible to obtain high-resolution images with an acceptable signal-to-noise (S/N) ratio by 3D data acquisition. This method has already been applied to MR myelography (10). Since an extremely long TR or TE is used, the acquired image is basically a heavily T2-weighted image in which the courses of small nerves and blood vessels are shown as distinct low-signal areas within the high-signal CSF. In particular, this method can be used to evaluate in detail the relationship between the brain stem, the facial nerve, and the blood vessels to identify the blood vessel presumed to be responsible for hemifacial spasm. The 3D-FSE method permits small peripheral branches of blood vessels to be displayed with high resolution, because the cerebral cisterns, nerves, and blood vessels are displayed with high contrast.

In the present study, the 3D-FSE technique was used to identify the blood vessel presumed to be responsible for hemifacial spasm and also to examine patients who have undergone neurovascular decompression surgery. This article addresses the clinical usefulness of the 3D-FSE method in these patients.

Methods

Twenty patients with hemifacial spasm were studied. The group included five men and 15 women (age range, 26 to 73 years; average age, 51 years) who were examined by 3D-FSE MR imaging between January 1995 and October 1996.

All 3D-FSE studies were performed with a 1.5-T MR system. Imaging parameters used for 3D-FSE sequence were 3000/250 (TR/TE), 1-mm-thick section, $192 \times 256 \times 32$ matrix, 27 echoes, and 32-mm slab thickness. Axial images, tilted 7° in the anteroinferior direction from the bicommissure line, were obtained, and midsection reconstruction postprocessing was used to generate images at 0.5-mm intervals. The time required for this sequence was approximately 12 minutes. The junction of the central and peripheral myelin of the facial nerve has been identified within 3 mm of the brain stem (11, 12). The blood vessels in contact with the nerve in this region adjacent to the brain stem were identified as those thought to be responsible for the hemifacial spasm. In all patients, the presumed responsible blood vessel was identified on the affected side, and contact between the blood vessels and the facial nerve in the REZ was ascertained.

Neurovascular decompression surgery was performed in eight patients in whom medical management was ineffective. In all patients, vertebral angiography was performed preoperatively to identify the responsible blood vessel, and the results of these diagnostic studies were then compared with intraoperative findings. In addition, a repeat 3D-FSE examination was performed within 6 months after surgery and the images obtained were compared with those obtained preoperatively.

Results

With the 3D-FSE method, the anatomic relationship between the nerves and blood vessels within the cistern can be determined precisely. Discrimination

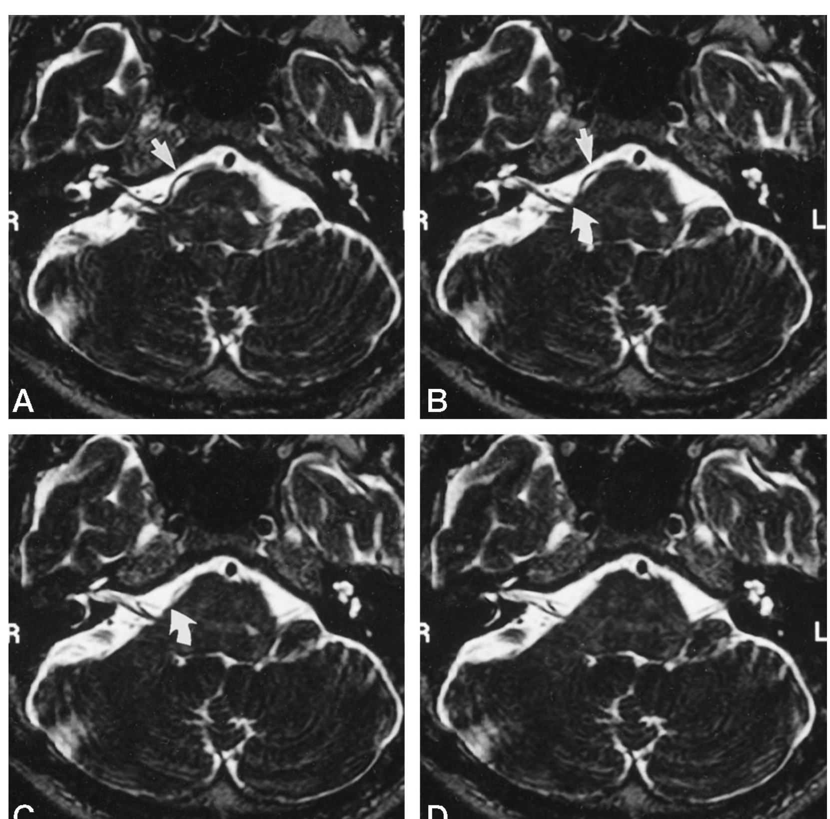


FIG 1. Axial FSE images in 40-year-old man with right hemifacial spasm.

A, AICA (*straight arrow*), which branches from the basilar artery, is clearly depicted as an arc-shaped structure reaching the internal acoustic foramen.

B, On an image acquired 0.5 mm above *A*, the REZ of the facial nerve (*curved arrow*) and the AICA (*straight arrow) are clearly recognized.*

C and *D*, Images of the other side show no structure compressing the REZ (*curved arrow* in *C* indicates facial nerve).

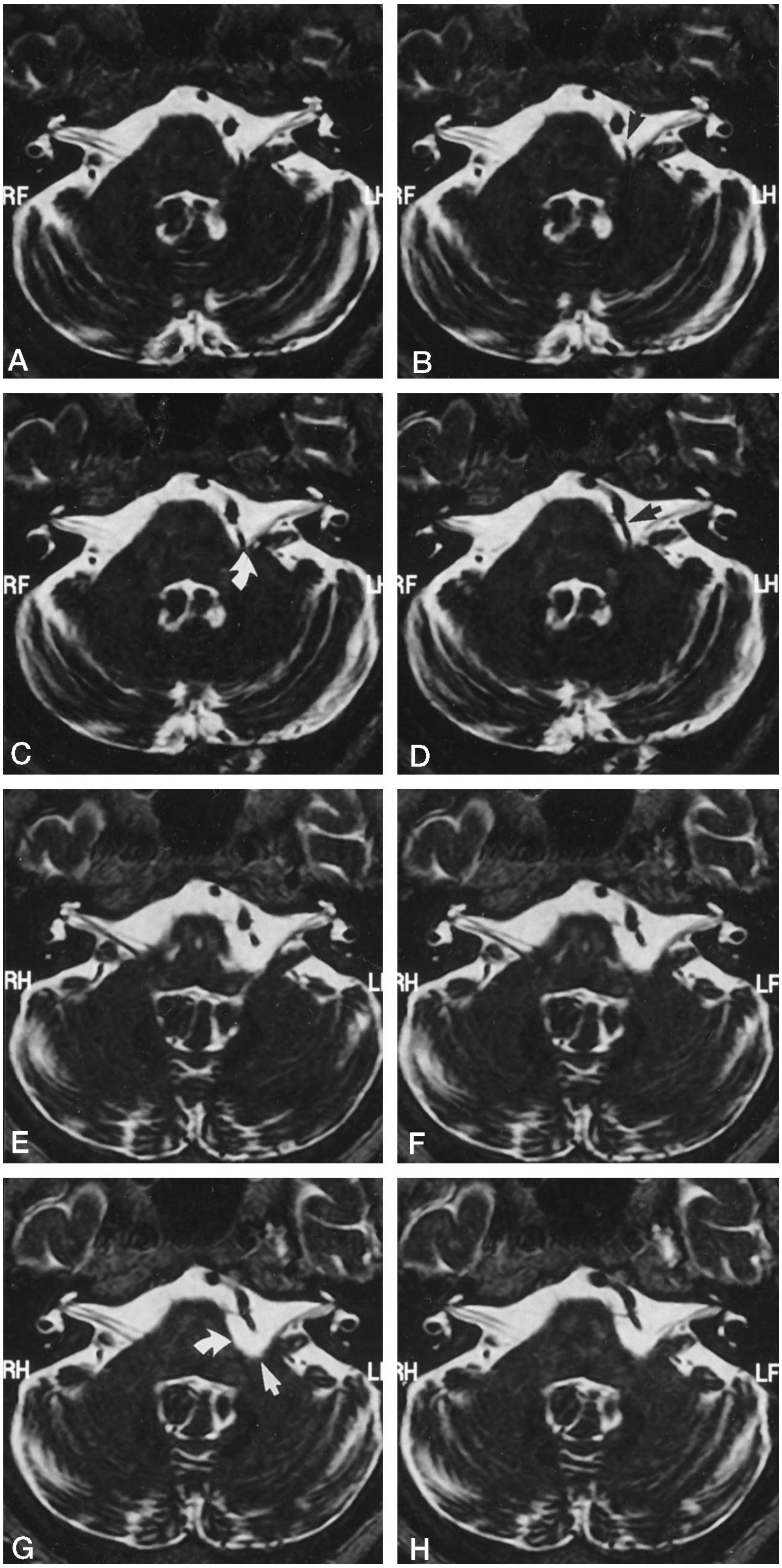


FIG 2. 62-year-old woman with left hemifacial spasm.

A–C, Preoperative axial FSE images depict the vertebral arteries bilaterally (*straight arrow* in *B* indicates PICA). The artery branching from the left vertebral artery impinges on the REZ of the facial nerve (*curved arrow, C*).

D, On an image acquired 1.5 mm above *A*, branching of the artery from the vertebral artery is confirmed, permitting the artery to be identified as the PICA (*arrow*).

E–H, On postoperative FSE images, the prosthesis (*curved arrow, G*) is depicted as a high-intensity area indistinguishable from the surrounding cistern. No structure was seen compressing the REZ of the facial nerve (*straight arrow, G*) and the PICA is shifted laterally.

and identification of the facial nerve and the vestibulocochlear complex were possible in all patients, with clear delineation of the REZ of the facial nerve immediately adjacent to the brain stem. The blood vessel presumably responsible for hemifacial spasm could be followed on both higher and lower sections, indicating that the structure was a vessel. The anterior inferior cerebellar artery (AICA), branching from the basilar artery, could also be delineated in several upper and lower sections, because the AICA reaches the meatal loop either anterior or posterior to the sixth cranial nerve after branching from the basilar artery, generally following a horizontal course (Fig 1). The posterior inferior cerebellar artery (PICA) could also be identified by following the artery from the point of compression to the lower sections, where it branched from the vertebral artery (Fig 2).

Among the 20 patients in the study, the artery responsible for hemifacial spasm was thought to be the AICA in 14, the PICA in four, and the vertebral artery in two. In all patients, the presumed responsible artery was in the REZ of the facial nerve. In addition, all symptoms in all patients appeared to be due to compression of the facial nerve by the responsible artery. A profile of the 20 patients with hemifacial spasm appears in Table 1.

Of the eight patients who underwent neurovascular decompression surgery, the actual responsible artery differed from that presumed on the basis of cerebral angiography in two cases (Table 2). In both these patients, an elongated vertebral artery was seen near the meatal loop of the AICA on 3D-FSE images; on cerebral angiograms, the vertebral artery was presumed to be the responsible artery on the basis of measurements of the distance from the midline at which the REZ was assumed to be located. Intraoperative findings revealed that the AICA was the responsible artery in these two patients. All eight patients were in satisfactory condition after surgery; they experienced no complications, and the hemifacial spasm resolved within 1 week. Postoperative 3D-FSE images confirmed that compression of the facial nerve by a blood vessel at the REZ was no longer present. Figures 2 and 3 show two representative cases.

TABLE 1: Profile of 20 patients with hemifacial spasm

Age (y)	
Mean	51
Range	26–73
Sex, n (%)	
Male	5 (25)
Female	15 (75)
Side of HFS, n (%)	
Left	11 (55)
Right	9 (45)
Responsible vessel as determined by 3D-FSE, n (%)	
AICA	14 (70)
PICA	4 (20)
VA	2 (10)

Note.—3D-FSE indicates 3D fast spin-echo MR imaging; AICA, anterior inferior cerebellar artery; PICA, posterior inferior cerebellar artery; VA, vertebral artery.

Discussion

Usefulness of 3D-FSE for the Preoperative Assessment of Hemifacial Spasm

The diagnosis of hemifacial spasm should be based on clinical symptoms, not on the findings of radiologic examinations. According to recent reports, the responsible blood vessels were identified in 99.4% of patients with hemifacial spasm who underwent neurovascular decompression; in 91% of these patients, symptoms were improved or eliminated (9, 13). Thus, responsible blood vessels are present in almost all patients with clinical symptoms, and in 90% or more of these patients, symptoms are attributable to nerve compression by the responsible artery. Accordingly, we hypothesized that compression must necessarily be present if symptoms are observed. Therefore, in our investigation, no attempt was made to distinguish between contact and compression, since responsible blood vessels were identified as those in contact with the facial nerve in the REZ on 3D-FSE MR images.

Previously, vertebral angiography alone was used to identify the compressing blood vessel, but in this method, it is necessary to calculate the position of the REZ of the facial nerve on the basis of surrounding bony structures, as the soft tissues of the brain stem, facial nerves, and so on cannot be visualized. Another

TABLE 2: MR, angiographic, and surgical findings in eight patients who underwent neurovascular decompression surgery

Case	Age (y)/Sex	Lesion Site	Preoperative Evaluation		Surgical Findings (Responsible Artery)	Postoperative Evaluation (Release of Compression as Seen at 3D-FSE)
			3D-FSE	Angiography		
1	42/F	F	AICA	AICA	AICA	+
2	61/F	R	AICA	AICA	AICA	+
3	56/F	L	AICA	AICA	AICA	+
4	59/F	L	AICA	AICA	AICA	+
5	62/F	L	AICA	VA	AICA	+
6	40/M	R	AICA	AICA	AICA	+
7	36/M	L	AICA	VA	AICA	+
8	57/M	L	PICA	PICA	PICA	+

Note.—3D-FSE indicates 3D fast spin-echo MR imaging; AICA, anterior inferior cerebellar artery; PICA, posterior inferior cerebellar artery; VA, vertebral artery.

limitation of vertebral angiography is that tumors, including meningiomas and dermoids, may not be depicted. Accordingly, CT or MR imaging has been performed to detect such lesions. MR imaging is superior to CT for evaluating lesions in the posterior cranial fossa, since it is not affected by bone artifacts (14). As a result, high-resolution images of the brain stem and cranial nerves can be acquired.

Several studies have reported that MR imaging with the conventional 2D Fourier transformation (2D-FT) method can be used to identify the presumed responsible artery in patients with hemifacial spasm. In these studies, various methods were used to identify the compressing artery at the REZ, as well as to make an overall evaluation of axial images by changing the section direction. In one method, the responsible artery at the REZ was identified as a vascular flow void (15); in another, oblique sagittal imaging was performed parallel to the course of the nerve (16). Furthermore, several studies, including those by Jannetta (6), have reported success in demonstrating the presence of vascular loop compression by superimposing MR angiograms on T1-weighted coronal images (17, 18). The section width should be as thin as possible to obtain precise information on the REZ of the facial nerve, which is an extremely small region. However, in the 2D-FT method, the thinner the section width, the lower the echo strength (because of the smaller number of protons contained in the section), resulting in deterioration of the S/N ratio.

With the 3D-FSE method, which is now available in clinical practice owing to recent advances in MR imaging technology (in particular, to the development of fast data processing techniques), it is possible to acquire high-resolution images using a 3D data acquisition technique while maintaining an acceptable S/N ratio. This method is expected to supplant conventional preoperative evaluation techniques, since the courses of small nerves and blood vessels can be displayed on the same image. In particular, it is necessary to evaluate the positional relationships among the brain stem, facial nerve, and blood vessels to identify the blood vessel presumed to be responsible for hemifacial spasm. The 3D-FSE method satisfies this requirement, as high-resolution images depict the cerebral cisterns as high-intensity areas and nerves and blood vessels running within the cisterns as low-intensity areas.

In previous studies with the 3D-FSE method, T1-weighted images have generally been acquired using the gradient-echo technique to identify the artery responsible for hemifacial spasm. Other fast imaging methods, such as the 3D fast low-angle shot technique (19), the contrast-enhanced 3D spoiled gradient-echo technique (20), and the fast imaging with steady-state precession technique (21), have also been reported to be useful for identifying the responsible artery. The 3D-FT method was used in each of these studies, although with different sequences, permitting the point of compression to be identified with a high level of confidence by acquiring high-resolution images in the optimal plane.

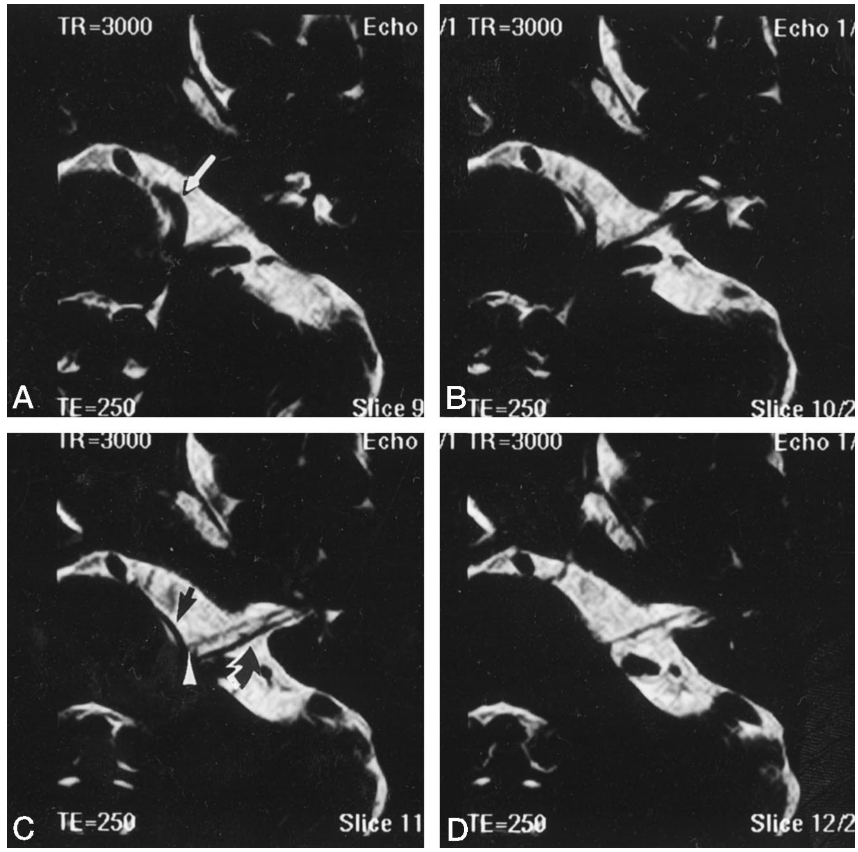
In the present study, we used the spin-echo method for the following reasons: 1) Images are basically heavily T2-weighted and of sufficiently high spatial resolution to delineate the cranial nerves and small blood vessels in detail as low-intensity areas, with the cerebral cisterns displayed as high-intensity areas. 2) The FSE method is suitable for imaging areas near the temporal pyramid, such as the cerebellopontine angle or the mastoid air cells, since the method is relatively unaffected by magnetic field nonuniformity; in particular, this method permits both the facial nerve and the vestibulocochlear complex, including even the fundus of the internal acoustic meatus, to be precisely depicted and accurately identified. 3) Because of its long TR and TE times, the FSE method is useful for delineating not only arteries but also veins, which exhibit slower blood flow as low-intensity areas; consequently, no contrast medium is required for imaging, as in the gradient-echo method, resulting in a noninvasive and cost-effective examination.

Unlike with the FSE method, in the gradient-echo method, in which contrast medium is used, nerves and blood vessels are clearly distinguishable, since blood vessels are displayed as high-intensity structures. Such discrimination is not possible with the FSE method, as both nerves and blood vessels are displayed as low-intensity structures. However, we thought that it would not be difficult for neurosurgeons or neuroradiologists to distinguish between nerves and blood vessels, because the seventh and eighth cranial nerves arise from the brain stem and run almost linearly toward the internal acoustic meatus, whereas blood vessels follow a curved path around the brain stem and may occasionally bifurcate.

In the 20 patients with hemifacial spasm in the present study, the facial nerve and the vestibulocochlear complex within the cerebellopontine cistern could be clearly distinguished. The courses of the small blood vessels, such as the AICA, the PICA, and so on, or the structure of, for example, the cerebellar flocculus, could be clearly seen in all patients, as could contact between the facial nerve and blood vessels at the REZ.

Usefulness of 3D-FSE for the Postoperative Assessment of Hemifacial Spasm

Postoperative 3D-FSE images showed displacement of the artery that had previously been compressing the facial nerve. In postoperative 3D-FSE images, at the least, no artery located adjacent to the facial nerve was recognized. These findings suggest that such images may be useful for postoperative evaluation. For example, if clinical symptoms are not improved or recur after surgery, it is extremely difficult to identify the cause; the facial nerve may be recompressed due to shifting of the implanted prosthesis, or irreversible demyelination may have developed. As a result, the surgeon faces a challenging decision as to whether to perform a second surgical procedure or to



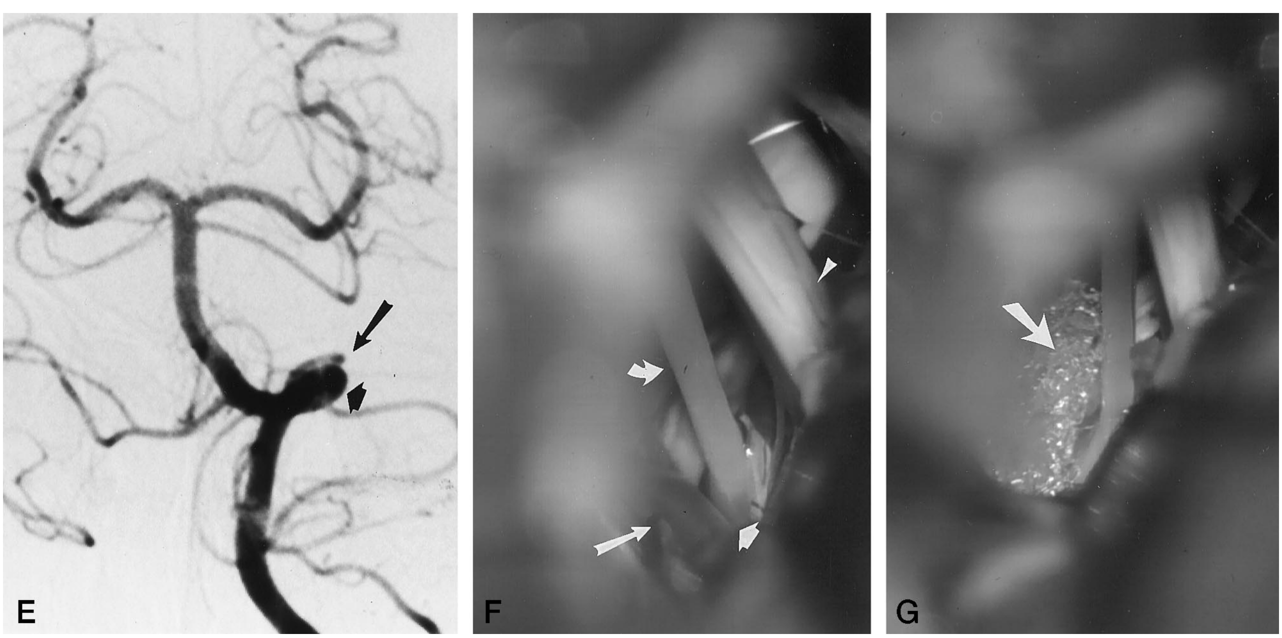


FIG 3. 36-year-old man with left hemifacial spasm.

A–D, On preoperative FSE images, the left vertebral artery (*arrow, A*) appears to impinge on the nerve root. However, it appears that it is the AICA (*straight arrow, C*) that impinges on the REZ of the facial nerve (*arrowhead, C*) on image acquired 1 mm above *A* (*curved arrow in C* indicates vestibulocochlear nerve).

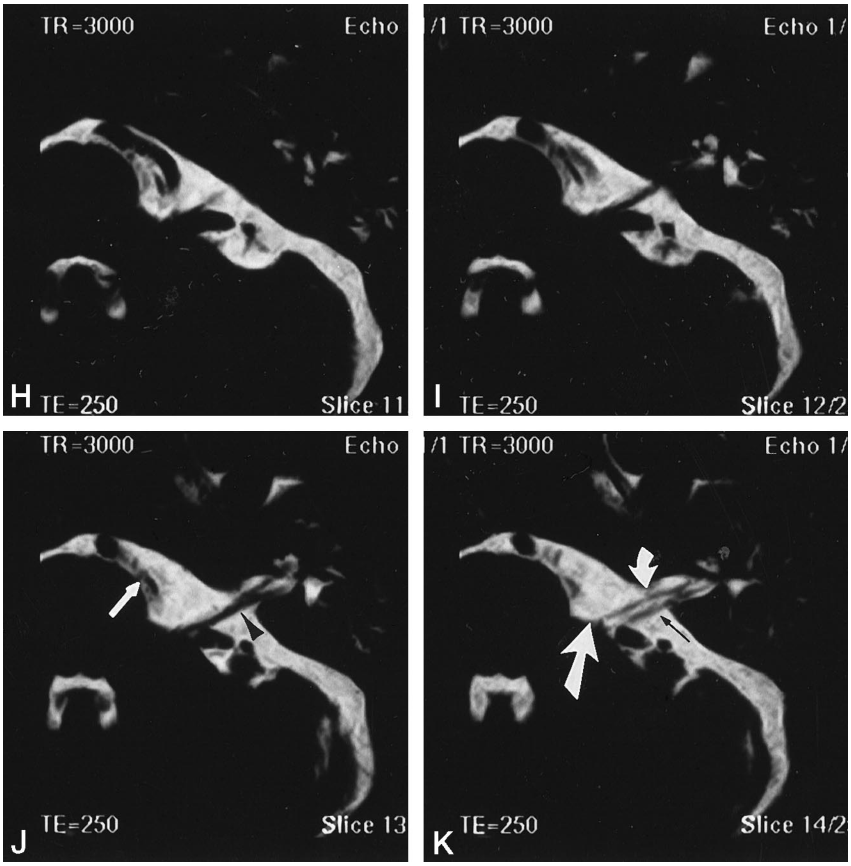
E, On preoperative cerebral angiogram, both the left vertebral artery (*short wide arrow*) and the AICA (*long thin arrow*) are recognized 13 mm lateral to the midline and cannot be identified as the artery responsible for hemifacial spasm.

F and *G*, On intraoperative photographs, the AICA (*long thin arrow*), which is thinner than the vertebral artery, is compressing the REZ of the facial nerve (*curved arrow*), which is identified as the responsible artery. A prosthesis (*arrow, G*) was placed between the AICA and the brain stem in order to decompress the facial nerve. (In *F*, *short wide arrow* indicates vascular compression; *arrowhead*, vestibulocochlear nerve.)

simply observe the patient's clinical course. In addition, the optimal timing for repeat surgery cannot be determined (9). In such cases, the effects of surgical decompression of the facial nerve can be evaluated by performing a repeat examination with 3D-FSE MR imaging and comparing the findings with preoperative images. The information obtained can be expected to be very useful in determining whether surgery is indicated.

Conclusion

The 3D-FSE technique makes it possible to obtain extremely high-quality images of microstructures in the cerebellopontine cistern, and it has several advantages over conventional angiography: it is noninvasive and able to depict the cranial nerves and surrounding vessels in the same image without contrast material, and it may be useful for postoperative evaluation of



H–K, On postoperative FSE images, the prosthesis (*slanted arrow*) is depicted as a high-intensity area indistinguishable from the surrounding cistern. The facial nerve (*curved arrow*) and vestibulocochlear complex (*straight black arrow*) are depicted. However, It is confirmed that no structure compressing the REZ is present. (In *J*, *straight arrow* indicates AICA; *black arrowhead*, vestibulocochlear nerve.)

the decompression procedure. This imaging technique is expected to prove useful for the clinical evaluation of hemifacial spasm.

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