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Trigeminal Neuralgia: Comparison of Two MR Imaging Techniques in the Demonstration of Neurovascular Contact¹

PURPOSE: To compare two magnetic resonance (MR) imaging techniques for demonstration of vascular contact with the trigeminal nerve.

MATERIALS AND METHODS: Thirteen patients with unilateral trigeminal neuralgia and 50 control subjects underwent three-dimensional fast inflow with steady-state precession (FISP) and contrast material-enhanced magnetization-prepared rapid acquisition gradient-echo (MP-RAGE) MR imaging. The images were independently reviewed by two neuroradiologists, who were blinded to the clinical details. Six of the 13 patients underwent surgery.

RESULTS: Vascular contact with the trigeminal nerve at the root entry zone was seen on FISP images in 10 of 13 (77%) symptomatic nerves and in eight of 113 (7%) asymptomatic nerves ($P < .001$). MP-RAGE and FISP images demonstrated arterial contacts equally well. MP-RAGE images demonstrated one additional venous contact at the root entry zone in a patient with ipsilateral trigeminal neuralgia. Interobserver agreement was good for both FISP ($\kappa = 0.69$) and MP-RAGE ($\kappa = 0.78$) images. The presence of vascular contact at the root entry zone, seen on preoperative MR images, was confirmed in all six patients who underwent surgery.

CONCLUSION: Both FISP and MP-RAGE MR imaging are useful in demonstrating vascular contact with the trigeminal nerve at the root entry zone in patients with trigeminal neuralgia.

THE main cause of trigeminal neuralgia (tic douloureux) is neurovascular compression at the root entry zone of the trigeminal nerve (1–3). The trigeminal nerve courses from the trigeminal (gasserian) ganglion through the prepontine cistern to enter the pons at the root entry zone. The root entry zone represents the transition zone between the peripheral and central myelin of the trigeminal nerve fibers. This junctional area is particularly vulnerable to continued pulsatile pressure, which may result in focal demyelination and short-circuiting of the impulses, which produces trigeminal neuralgia (1,4).

Trigeminal neuralgia is characterized by paroxysmal facial pain, which is usually confined to the second, third, or, occasionally, first division of the fifth cranial nerve. In the majority of cases, compression at the root entry zone is caused by a tortuous, elongated superior cerebellar artery. Less frequently, compression is caused by veins (eg, the petrosal vein), an elongated anterior inferior cerebellar artery, or vertebral basilar dolichoectasia (1–5). Vascular contact of posterior fossa vessels with the cisternal segment of the trigeminal nerve is considered to be irrelevant. When typical trigeminal neuralgia is the only symptom and the findings from a neuro-

logic examination are normal, other diseases of the nervous system such as multiple sclerosis or tumors that compress the trigeminal nerve root are rarely the cause of this condition (6–9).

Although many patients experience adequate relief of symptoms when treated with carbamazepine or other drugs, some patients require surgical treatment because the symptoms are intractable or because they cannot tolerate medications (4). In a large study (3) of patients who underwent posterior fossa surgery for trigeminal neuralgia, microvascular decompression proved to be a safe and effective treatment and had a high rate of long-term success. Without preoperative imaging, however, no cause of the symptoms can be found at surgery in 10%–30% of cases (1,2,10).

Microvascular decompression is recommended as the procedure of choice for the treatment of trigeminal neuralgia in patients who have undergone unsuccessful medical therapy (1–4). This procedure should not be delayed, because prolonged medical therapy may ultimately reduce the efficacy of surgery by allowing a reversible compressive lesion sufficient time to develop into an intrinsic disorder of conduction with subsequent irreversible damage to the nerve (11).

To determine those patients who

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Abbreviations: FISP = fast inflow with steady-state precession, MP-RAGE = magnetization-prepared rapid acquisition gradient echo, 3D = three-dimensional.

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Table 1
MR Imaging Findings of
Neurovascular Contact at the
Root Entry Zone of the
Trigeminal Nerve

Finding	No. of Trigeminal Nerves		Total
	Sympto- matic	Asympto- matic	
FISP images			
Present	10	8	18
Absent	3	105	108
Total	13	113	126
MP-RAGE images			
Present	10	7	17
Absent	3	106	109
Total	13	113	126

may benefit from microvascular decompression of the trigeminal nerve, three-dimensional (3D) fast inflow with steady-state precession (FISP) magnetic resonance (MR) imaging has been advocated (10,12) as a highly sensitive and specific method for demonstrating vascular compression. The authors of other studies (13,14) have suggested that 3D fast low-angle shot MR imaging with the magnetization-prepared rapid acquisition gradient-echo (MP-RAGE) sequence is also useful. A disadvantage of 3D FISP MR imaging compared with MP-RAGE MR imaging is that other causes of trigeminal neuralgia, such as tumors, may be more easily overlooked, owing to increased background suppression with 3D FISP imaging.

The authors of previous MR imaging studies (10,12,13,15) of neurovascular contact focused primarily on the demonstration of arterial contacts. Demonstration of venous contact is important, however, because venous compression is an important predictor of eventual recurrence of trigeminal neuralgia after microvascular decompression (3). Some authors (10,12) have suggested that administration of contrast material may add to the accuracy of the demonstration of vascular contact by allowing visualization of venous contact. Contrast material, however, was not used routinely in these studies, neither in control subjects nor in patients. A possible advantage of contrast-enhanced MP-RAGE MR imaging over 3D FISP imaging is that both arterial and venous contacts can be demonstrated and tumors can be excluded with the use of only one imaging sequence. To our knowledge, these two gradient-echo MR imaging techniques have not been compared in terms of the ability to depict vascular contacts with the trigeminal nerve.

Figure 1. Right trigeminal neuralgia caused by compression at the root entry zone by means of the superior cerebellar artery in a 71-year-old woman. (a) Coronal 3D FISP MR image (33/8, one signal acquired, 20° flip angle) shows right superior cerebellar artery (large arrow) in contact with the root entry zone of right trigeminal nerve (small arrow). (b) MR angiogram (coronal projection) obtained by postprocessing the 3D FISP data set with a maximum intensity projection algorithm shows the downward loop of right superior cerebellar artery (arrow). (c) Coronal contrast-enhanced MP-RAGE MR image (10/4, one signal acquired, 12° flip angle) shows the right superior cerebellar artery (black arrow) in contact with the root entry zone of the right trigeminal nerve (white arrow). The superior cerebellar artery was identified by tracing it back to the basilar artery. The imaging findings were confirmed at surgery.

The purpose of this study was to compare 3D FISP and contrast-enhanced MP-RAGE MR imaging findings for demonstration of arterial contacts with the trigeminal nerve and to assess the additional value of contrast-enhanced MP-RAGE in demonstrating venous contacts in patients with trigeminal neuralgia and in control subjects.

MATERIALS AND METHODS

Between March 1994 and January 1997, 13 patients (six men and seven women), aged 21–77 years (mean, 57 years), with medically intractable unilateral trigeminal neuralgia (five patients with left-sided neuralgia and eight with right-sided neuralgia) and 50 control subjects (22 men and 28 women), aged 19–86 years (mean, 51 years), underwent MR imaging with a 1.5-T unit (Magnetom; Siemens Medical Systems, Erlangen, Germany). All patients with trigeminal neuralgia had been treated unsuccessfully with or were intolerant of

medical treatment with carbamazepine ($n = 13$ [100%]), phenytoin ($n = 6$ [46%]), baclofen ($n = 3$ [23%]), or other drugs ($n = 3$ [23%]). Duration of symptoms at the time of MR imaging varied from 8 months to 14 years (mean, 4½ years). The control group comprised patients with sensorineural hearing loss but without trigeminal neuralgia; the subjects had been referred for cerebellopontine-angle MR imaging because they were suspected of having acoustic schwannoma. Findings from T1-weighted spin-echo MR images in the control subjects were normal.

All patients and control subjects underwent 3D FISP and contrast-enhanced MP-RAGE MR imaging to detect neurovascular contact with the fifth cranial nerve in the posterior fossa. Informed consent and appropriate approval were obtained. After the patient was positioned in the head coil, a sagittal localizer (15/6 [repetition time msec/echo time msec], one signal acquired, 8-mm section thickness, 30-cm field of view, 128 × 256 matrix) was obtained. A 3D FISP sequence (33/8, one signal acquired, 20° flip angle, 64-mm slab thick-

a.

b.

c.

Figure 2. Right trigeminal neuralgia caused by compression at the root entry zone by means of the superior cerebellar and anterior inferior cerebellar arteries in a 49-year-old man. (a) Coronal 3D FISP MR image (33/8, one signal acquired, 20° flip angle) shows the downward loop of the right superior cerebellar artery (open arrow) and the upward loop of the right anterior inferior cerebellar artery (solid straight arrow) compressing the root entry zone of the right trigeminal nerve (curved arrow). (b) MR angiogram obtained by postprocessing the 3D FISP data set with a maximum intensity projection algorithm (coronal projection, rotated 30° to a right anterior oblique position) shows the downward loop of the right superior cerebellar artery (open arrow) and the upward loop of the right anterior inferior cerebellar artery (solid arrow) in proximity to each other near the root entry zone of the right trigeminal nerve. (c) Coronal contrast-enhanced MP-RAGE MR image (10/4, one signal acquired, 12° flip angle) shows the right superior cerebellar artery (open arrow) and the right anterior inferior cerebellar artery (solid black arrow) compressing the root entry zone of the right trigeminal nerve (solid white arrow). The vessels were identified by tracing them back to the basilar artery. The imaging findings were confirmed at surgery.

ness with 64 partitions [1-mm effective section thickness], 20-cm field of view, 192 × 512 matrix, 8-minute acquisition time) was used, with a parallel saturation slab placed superiorly to eliminate the signal from venous flow. Three-dimensional time-of-flight MR angiograms of the posterior fossa were reconstructed from the 3D FISP source images by using a maximum intensity projection algorithm. The individual axial 3D FISP images were inspected; after identification of the trigeminal nerves, volume editing was performed to include the trigeminal nerves, the pons, and the region of the trigeminal cavity (Meckel cave). Contiguous coronal reformations, with a section thickness of 1 mm (MR tomographic angiograms), were obtained through the pons by commencing behind the trigeminal nerves and continuing to the level of the trigeminal ganglia.

After 3D FISP imaging, all patients and control subjects underwent MP-RAGE imaging (10/4, one signal acquired, 12° flip angle, 170-mm slab thickness with 170 partitions [1-mm effective section thickness], 25-cm field of view, 256 × 256 matrix, 6.5-minute acquisition time) after an intravenous injection of 0.1 mmol gadodiamide (Omniscan; Nycomed, Oslo, Norway) per kilogram of body weight. Coronal 1-mm-thick reconstructions of the pons and the preganglionic segments of trigeminal nerves were performed. On the contrast-enhanced MP-RAGE images, arteries were identified by tracing the vessel to the origin in the basilar artery; veins were identified on the basis of their appearance as enhancing, bright structures amid the low-signal-intensity cerebrospinal fluid, which could not be traced to the basilar artery.

The patients with trigeminal neuralgia

also underwent axial proton-density, T2-weighted, and axial and coronal pre- and postcontrast T1-weighted spin-echo MR imaging to exclude other lesions such as tumors and lesions from multiple sclerosis as the cause of the neuralgia. Patients with tumors or with multiple sclerosis were not included in this study.

All 3D FISP images (MR angiograms and MR tomographic angiograms) and contrast-enhanced MP-RAGE images were independently analyzed by two neuroradiologists (C.B.L.M.M., F.J.H.), who were blinded to the clinical findings. The quality of the visualization of the trigeminal nerves and of the posterior fossa vessels was assessed, the presence of vascular contact with the trigeminal nerve at the root entry zone was determined, and the nature of the involved vessels was identified. The image was considered to be positive when vascular contact at the root entry zone was present. After the blinded study, discrepancies were resolved by means of consensus.

The results were analyzed by using the χ^2 test; interobserver variability was assessed with the κ statistic. Surgical findings were available for correlation with the MR imaging findings in six patients, who underwent microvascular decompression.

RESULTS

The preganglionic segment of the trigeminal nerve was well visualized in all patients and in all control subjects on the coronal 3D FISP MR tomographic angiograms and on the coronal contrast-enhanced MP-RAGE images. MR angiograms obtained by processing the 3D FISP data set with a maximum intensity projection algorithm demonstrated all 126 (100%) superior cerebellar arteries, all 63 (100%) basilar arteries, 125 of 126 (99%) posterior cerebral arteries, 83 of 126 (66%) anterior inferior cerebellar arteries, 102 of 126 (81%) vertebral arteries, and 65 of 126 (52%) posterior inferior cerebellar arteries.

There was complete agreement between the two observers with regard to the visualization of the superior cerebellar, basilar, posterior cerebral, and vertebral arteries. There was a high degree of agreement with regard to the visualization of the anterior inferior cerebellar artery ($\kappa = 0.89$) and the posterior inferior cerebellar arteries ($\kappa = 0.93$).

Vascular contact of the trigeminal nerve at the root entry zone was demonstrated on 3D FISP images in 10 of 13 (77%) symptomatic nerves and in eight of 113 (7%) asymptomatic nerves (Table 1). The difference between the two groups of nerves was statistically significant ($P < .001$). Three-dimensional FISP images showed a single artery in contact with the nerve at the

root entry zone of symptomatic nerves in nine patients (the superior cerebellar artery in six patients and the anterior inferior cerebellar artery in three patients) (Fig 1) and two arteries in contact with a symptomatic nerve in one patient (superior cerebellar and anterior inferior cerebellar arteries) (Fig 2). No venous contacts were seen on 3D FISP images.

Contrast-enhanced MP-RAGE images demonstrated vascular contact with the trigeminal nerve at the root entry zone in 10 of 13 (77%) symptomatic nerves and in seven of 113 (6%) asymptomatic nerves (Table 1). The difference between the two groups of nerves was statistically significant ($P < .001$). Contrast-enhanced MP-RAGE images showed a single artery in contact with symptomatic nerves at the root entry zone in eight patients (the superior cerebellar artery in five patients and the anterior inferior cerebellar artery in three patients) (Fig 1) and two vessels in contact with symptomatic nerves in two patients (the superior cerebellar and anterior inferior cerebellar arteries in one patient [Fig 2] and the superior cerebellar artery and a vein in the other patient [Fig 3]). Compared with 3D FISP images, contrast-enhanced MP-RAGE images demonstrated the same arterial contacts with symptomatic nerves, in addition to one venous contact with a symptomatic nerve at the root entry zone in a patient who had contact between the nerve and two vessels (the superior cerebellar artery and a vein). Nine additional venous contacts with cisternal segments of asymptomatic nerves were seen on contrast-enhanced MP-RAGE images (Fig 4).

There was a good degree of agreement between the two observers with regard to the presence of vascular contact at the root entry zone of symptomatic and asymptomatic trigeminal nerves with both the 3D FISP images ($\kappa = 0.69$) and the contrast-enhanced MP-RAGE images ($\kappa = 0.78$). The difference in interobserver agreement was not statistically significant ($P > .2$).

The presence of vascular contacts at the root entry zone, which was visible on preoperative MR images, was confirmed in all six patients who underwent surgery. These patients had complete relief of neuralgia after microvascular decompression.

DISCUSSION

The results of previous studies (10,12,17) in which various MR imaging sequences were used have shown vascular contact at the root entry zone

Figure 3. Right trigeminal neuralgia caused by compression at the root entry zone by means of the superior cerebellar artery and a vein in a 72-year-old man. (a) Coronal 3D FISP MR image (33/8, one signal acquired, 20° flip angle) shows only the superior cerebellar artery (open arrow) in contact with the root entry zone of the right trigeminal nerve (solid arrow). (b) Coronal contrast-enhanced MP-RAGE MR image (10/4, one signal acquired, 12° flip angle) shows the right trigeminal nerve compressed at the root entry zone (solid black arrow) by means of two vessels, including the superior cerebellar artery (open arrow) and a vein (solid white arrow).

Figure 4. Contact of a vein with the cisternal segment of the left trigeminal nerve in a 48-year-old control patient without trigeminal neuralgia. (a) Coronal 3D FISP MR image (33/8, one signal acquired, 20° flip angle) does not show vascular contact with the cisternal segment of the left trigeminal nerve (arrow). (b) Coronal contrast-enhanced MP-RAGE MR image (10/4, one signal acquired, 12° flip angle) shows contact of a vein (solid arrow) with the cisternal segment of the left trigeminal nerve (open arrow).

a.

b.

of the trigeminal nerve in 57%–100% of symptomatic nerves and in 8%–32% of asymptomatic (control) nerves (Table 2).

Coronal T1-weighted spin-echo MR images obtained with a 3-mm section thickness have been used to demonstrate vascular contact with the trigeminal nerve. In these studies (16,17), a relatively high percentage (27%–32%) of patients had vascular contact at the root entry zone of asymptomatic nerves. This relatively high prevalence may be due to partial volume averaging (because of the small vessel size in relation to section thickness) and to the simultaneous depiction of arteries and veins as signal voids (10). The nature of the vessels in contact with the nerve could not be determined with this technique. Contrast resolution is limited on T1-weighted spin-echo MR images because cerebrospinal fluid is dark gray and a flow void is black on these images. Hutchins et al (17) stress that the use of conventional spin-echo MR images will permit exclusion of other lesions such as neoplasms, but, in patients with trigeminal neuralgia, these images are

not helpful in the selection of candidates for microvascular decompression.

Because vascular compression can be demonstrated only when the vascular structures and the nerves are visualized simultaneously, both spatial and contrast resolution must be of sufficient quality. The nerve and the vessels can be well visualized by using gradient-echo sequences such as 3D FISP and MP-RAGE sequences (10,12–15). Because these sequences

Table 2
MR Imaging Findings of Neurovascular Contact Reported in the Literature

A: Symptomatic Trigeminal Nerves

Study	No. of Nerves	No. of Vascular Contacts*	No. of Microvascular Decompressions	No. of Confirmed Imaging Findings†	MR Imaging Technique‡
Hutchins et al (17)	29	16 (57)	6	6	T1-weighted spin echo, 3-mm section thickness
Tash et al (16)	6	6 (100)	3	3	T1-weighted spin echo, 3-mm section thickness
Sens and Higer (14)	5	5 (100)	0	0	3D fast low-angle shot; gadolinium-enhanced, 1-mm section thickness
Furuya et al (13)	4	3 (75)	4	3§	3D fast low-angle shot, 0.8-mm section thickness
Nagaseki et al (15)	7	6 (86)	4	4	Gradient echo, 3-mm section thickness
Meaney et al (10)	40	28 (70)	25	25	3D FISP MR angiography and MR tomographic angiography
	...	6 (15)	...	...	Gadolinium enhanced, 1-mm section thickness (<i>n</i> = 10)
Meaney et al (12)	55	42 (76)	52	50	3D FISP MR angiography and MR tomographic angiography
	...	9 (16)	...	...	Gadolinium enhanced, 1-mm section thickness (<i>n</i> = 10)
Present study	13	10 (77)	6	6	3D FISP MR angiography and MR tomographic angiography, 1-mm section thickness
	13	10 (77)	6	6	Contrast-enhanced MP-RAGE, 1-mm section thickness

B. Asymptomatic Trigeminal Nerves

Study	No. of Nerves	No. of Vascular Contacts*	MR Imaging Technique‡
Hutchins et al (17)*	60	16 (27)	T1-weighted spin echo, 3-mm section thickness
Tash et al (16)*	170	54 (32)	T1-weighted spin echo, 3-mm section thickness
Meaney et al (10)	114	9 (8)	3D FISP MR angiography and MR tomographic angiography, 1-mm section thickness
Meaney et al (12)	45	4 (9)	3D FISP MR angiography and MR tomographic angiography, 1-mm section thickness
Present study	113	8 (7)	3D FISP MR angiography and MR tomographic angiography, 1-mm section thickness
	113	7 (6)	Contrast-enhanced MP-RAGE, 1-mm section thickness

* Numbers in parentheses are percentages.

† Imaging findings were confirmed with results from surgical examination.

‡ Section thickness refers to coronal sections.

§ One case of venous compression at the root entry zone was overlooked on MR images.

|| Two cases of venous compression at the root entry zone were overlooked on MR images.

* Identification of vessels was not possible.

have no 180° pulse, dephasing after the 90° pulse is minimized, and even fast-flowing blood produces a high signal intensity. This effect can be further emphasized with gadolinium enhancement, which results in T1 shortening with subsequent signal intensity enhancement. Another advantage of gradient-echo MR imaging is the ability to acquire an entire 3D data set with an effective section thickness of as little as 0.8 mm and no intersection gaps, which thereby limits partial volume effects. The resulting voxels are isotropic, allowing the calculation of reconstructions in any desired plane (14). Sens and Higer (14) used contrast-enhanced 3D fast low-angle shot MR imaging to demonstrate vascular contact at the root entry zone of symptomatic nerves in all five patients with unilateral trigeminal neuralgia in their series.

In two previous studies (10,12) of 40 and 55 patients, 3D FISP imaging was used to demonstrate vascular contact with the trigeminal nerve. With this technique, there is good contrast resolution between the high signal intensity of flowing blood, the intermediate signal intensity of cranial nerves, and

the low signal intensity of cerebrospinal fluid. Coronal reconstructions (MR tomographic angiograms) and MR angiograms can be derived from the 3D data set, which enable both visualization of neurovascular contact and exact identification of the vessel involved. With this technique, only arteries are visualized owing to the venous presaturation slab used to obtain MR angiograms (18). Veins can be demonstrated with the administration of contrast material, but this procedure will degrade the maximum intensity projection MR angiograms by decreasing background suppression.

In the aforementioned studies (10,12), vascular contact at the root entry zone was demonstrated in 70%–76% of symptomatic nerves and in 8%–9% of asymptomatic (control) nerves. Contrast-enhanced MR imaging was performed only in patients with normal findings on unenhanced MR images. In four of 10 and in nine of 10 patients in whom contrast material was administered, a vein was seen in contact with the nerve at the root entry zone on the symptomatic side.

Our study was designed to compare the findings from 3D FISP MR imaging

(MR angiography and MR tomographic angiography) and contrast-enhanced MP-RAGE MR imaging in the demonstration of arterial contacts and to assess the added value of contrast-enhanced MP-RAGE imaging for the demonstration of venous contacts.

By using 3D FISP imaging (MR angiography and MR tomographic angiography), we visualized arterial contacts at the root entry zone in 10 of 13 (77%) symptomatic nerves and in eight of 113 (7%) asymptomatic nerves. This difference was statistically significant (*P* < .001). These findings correspond well with those in the studies by Meaney et al (10,12).

Contrast-enhanced MP-RAGE imaging was equal to 3D FISP imaging in terms of the demonstration of arterial contacts. The additional value of contrast-enhanced MP-RAGE imaging, compared with 3D FISP imaging, was limited: Contrast-enhanced MP-RAGE images depicted only one additional venous contact at the root entry zone in a patient with ipsilateral trigeminal neuralgia; the nerve in this patient was also in contact with the superior cerebellar artery. This result represents 10% of all patients with

vascular contact in our series and is comparable with the lower limit of the percentages (10%–68%) of venous contacts reported in anatomic and surgical studies (1–3,19–21).

The advantage of 3D FISP imaging over contrast-enhanced MP-RAGE imaging is that, with the former, a high-quality MR angiogram can be obtained with maximum intensity projection postprocessing of the 3D FISP data set. This MR angiogram facilitates identification of the vessel involved. At the expense of more imaging time, additional contrast-enhanced 3D FISP imaging may be needed to demonstrate venous contacts (10,12). A disadvantage of 3D FISP imaging compared with contrast-enhanced MP-RAGE imaging is that, owing to greater background suppression, other causes of trigeminal neuralgia (eg, tumors) may be overlooked more easily. Other MR imaging methods (eg, pre- and postcontrast T1-weighted spin-echo MR imaging) are needed to exclude tumors, which are the cause of trigeminal neuralgia in 2%–4% of cases (1,9).

Contrast-enhanced MP-RAGE imaging has the potential advantage that, with the use of only one imaging sequence, both arterial and venous contacts can be demonstrated and tumors can be excluded. A precontrast T1-weighted spin-echo MR image is needed to characterize lesions, such as those due to hemorrhage or lipoma, that are intrinsically bright with T1-weighting. Acquisition of axial T2-weighted spin-echo or fast spin-echo MR images is necessary with both 3D

FISP and contrast-enhanced MP-RAGE imaging to exclude multiple sclerosis, which may be the cause of trigeminal neuralgia in 1%–2% of cases (6).

In conclusion, both 3D FISP and contrast-enhanced MP-RAGE MR imaging are useful in the demonstration of neurovascular contact at the root entry zone in patients with trigeminal neuralgia. The value of contrast-enhanced MP-RAGE MR imaging for the additional demonstration of venous contacts was limited. ■

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