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BACKGROUND AND PURPOSE: **We attempted to identify the cause of abnormal venous flow seen during arterial MR angiography in the inferior petrosal sinus by use of in three female patients (aged 51, 48, and 70 years, respectively).**

METHODS: **Arterial 3D time-of-flight MR angiography was performed with a tilted optimized nonsaturating excitation pulse sequence (TR/TE, 31/7; flip angle, 20 degrees; section thickness, 65 mm; effective thickness, 1 mm; number of sections, 1 to 2); no magnetization transfer pulse sequence was used. Contrast-enhanced 3D MR angiography of the neck was performed with a 3D fast low-angle shot pulse sequence (TR/TE, 4.6/1.8; flip angle, 40 to 45 degrees; section thickness, 80 mm; intersection gap, 1.5 mm; acquisition matrix, 180 × 256; acquisition time, 27 s) on a system with a whole-body coil.**

RESULTS: **In all three patients, 3D time-of-flight MR angiography revealed abnormal vascular signal originating from the left cavernous sinus, continuing through the inferior petrosal sinus, and ending in the proximal internal jugular vein at the jugular bulb level. Abnormal vascular signal at the jugular bulb, sluggish flow and flow-related enhancement in the left internal jugular vein, and signal void in the contralateral jugular vein were noted. Contrast-enhanced delayed-phase MR angiography showed stenosis in the left brachiocephalic vein in all patients.**

CONCLUSION: **High signal intensity noted at the inferior petrosal sinus resulted from retrograde flow. Retrograde flow was due to blood stealing from the internal jugular vein toward the cavernous sinus because of venous stenosis in the brachiocephalic vein.**

Several reports in the literature have shown that MR angiography is effective in showing abnormal venous flow in the cavernous sinus compartment, pericavernous space, and inferior petrosal sinus (1–4). These abnormal venous signals have been attributed to the presence of a carotid cavernous fistula (1–3, 5) or technical factors. We herein report the cases of three patients in whom abnormal flow in the left jugular bulb and inferior petrosal sinuses was shown to be caused by retrograde flow due to brachiocephalic vein stenosis.

Methods

Abnormal venous flow in the inferior petrosal sinus was assessed by use of arterial MR angiography in three female patients (aged 51, 48, and 70 years, respectively). All three patients underwent the following imaging protocols.

Conventional MR imaging with transverse proton density– and T2-weighted sequences, transverse and sagittal T1-weighted sequences, and coronal fluid-attenuated inversion recovery sequences. MR imaging and MR angiography were performed with a 1.5-T unit (Magnetom Vision Plus; Siemens, Erlangen, Germany). Cranial arterial MR angiograms were obtained by using a 3D time-of-flight technique without magnetization transverse pulse but with tilted optimized nonsaturating excitation pulse. Imaging parameters were 31/7 (TR/TE); flip angle, 20 degrees; section thickness, 65 mm; effective thickness, 1 mm; number of sections, one to two. Cranial venous MR angiograms were obtained by using a 2D time-of-flight technique: fast low angle shot; 30/2; thickness, 2 mm; distance factor, −0.33; matrix, 224 × 256; field of view, 200 mm; axial plane.

Contrast-enhanced 3D MR angiography was performed with a 3D fast low angle shot sequence by using a whole body coil. In the evaluation of central veins, the 3D acquisition volume was placed in the coronal plane. To place the 3D acquisition volumes, broadly spaced 10-mm axial 2D time-of-flight images were acquired. During contrast-enhanced 3D MR angiography, the field of view was 375 mm. The rectangular field of view was adapted. Imaging parameters were 4.6/1.8; flip angle, 40 to 45 degrees; section thickness, 80 mm; effective

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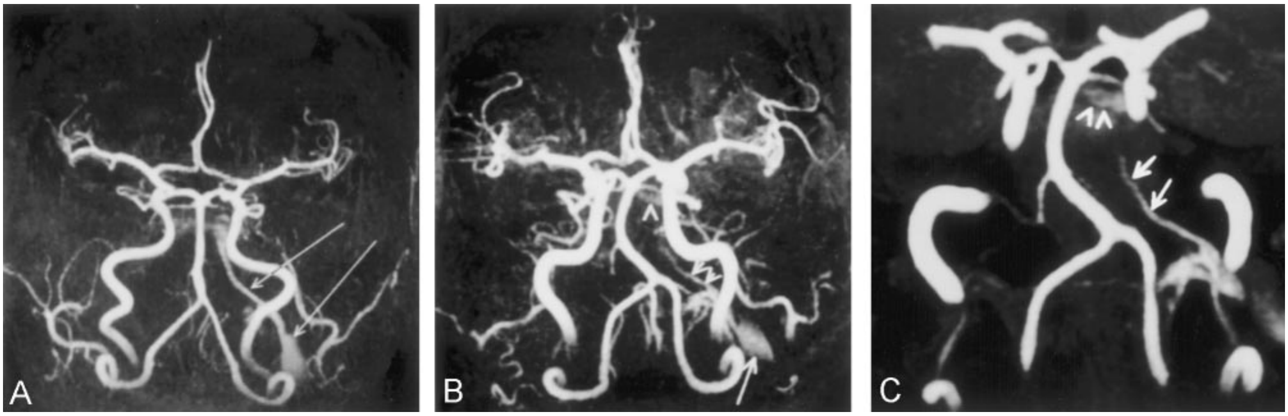


FIG 1. Abnormal vascular signal intensity was seen in the left jugular bulb, inferior petrosal sinus, and cavernous sinus.

A, 3D time-of-flight cranial arterial MR angiogram of the first patient shows high signal intensity in the left cavernous sinus together with the left inferior petrosal sinus and internal jugular vein at the level of the jugular bulb (*arrows*).

B, MR angiogram of the second patient shows abnormal flow-related enhancement in the left inferior petrosal sinus because of a fistula (*arrowhead*, cavernous sinus; *double arrowheads*, inferior petrosal sinus; *arrow*, jugular bulb).

C, Subvolumetric reconstructed maximum intensity projection image of the third patient shows more details of the inferior petrosal and cavernous sinuses (*arrowheads*, cavernous sinus; *arrows*, inferior petrosal sinus).

thickness, 1.5 mm; acquisition matrix, 180 × 256; acquisition time, 27 s. For subtraction of arteries, enhanced arterial phase mask images of the vascular territories were first acquired and then venous phase images were immediately acquired. Paramagnetic contrast agent (2 mmol/kg of body weight, Magnevist [Schering, Berlin, Germany] or Omniscan [Nycomed, Oslo, Norway]) was injected via other upper limb vein. After the injection of contrast agent, two measurements were obtained. The time between the two measurements was 0 s. The second measurement was for observing the delayed enhancement and venous return.

Contrast-enhanced mask images were reconstructed by using a maximal intensity projection technique. Moreover, arterial phase enhanced mask images were automatically subtracted from the contrast-enhanced mask images and orthogonal maximum intensity projections of subtracted images were reconstructed again. Use of subtraction enables clear visualization of the enhanced vein lumen by eliminating background arterial signal.

Results

Case 1

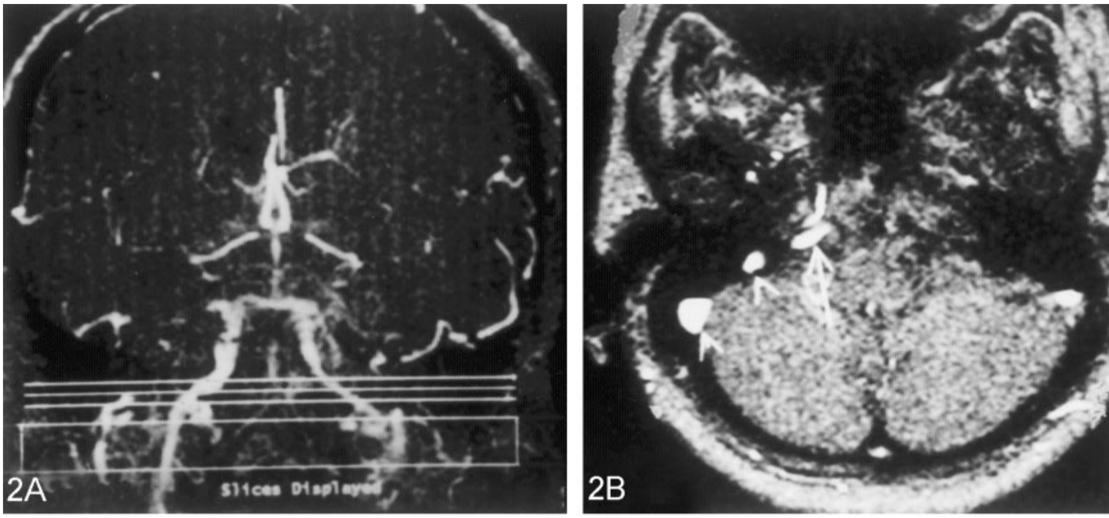
A 51-year-old hypertensive woman presented with symptoms of vertebrobasilar insufficiency and fluctuating pain in the left part of her head. The results of cranial MR imaging were unremarkable.

During arterial 3D time-of-flight MR angiography, an abnormally hyperintense vascular signal was seen beginning from the left cavernous sinus and ending in the proximal internal jugular vein at the left jugular bulb. Hyperintense vascular signal was also seen in the jugular bulb (Fig 1). However, on the contralateral side, no hyperintense signal was observed from these structures. On the maximum intensity projection images, a vascular structure between the cavernous sinus and left jugular bulb was observed and was thought to be the left inferior petrosal sinus. Signal intensity of this vascular structure was less high than the arterial signal intensity (Fig 1). We considered that a carotid cavernous fistula might have caused it, and we recommended that the patient undergo digital subtraction angiography.

Digital subtraction angiography showed neither a carotid cavernous fistula nor an abnormal flow in the cavernous sinus. Because the digital subtraction angiography was performed at another center, we could not obtain any information regarding flow in the inferior petrosal sinus. We then performed venous MR angiography. On venous MR angiograms, both inferior petrosal sinuses showed high signal intensity, because the saturation band was at a more caudal level than the jugular foramen and was not traveling saturation. Once we had saturated the flow at the proximal edge of the inferior petrosal sinus, the flow signal intensity in the left inferior petrosal sinus was saturated, whereas the flow-related enhancement in the contralateral inferior petrosal sinus was not (Fig 2). On the contrary, once we had saturated the flow in the distal inferior petrosal sinus toward a caudal direction, high signal intensity was seen in the left inferior petrosal sinus, but flow signal intensity in the right inferior petrosal sinus was saturated (Fig 3). We thus concluded that the high signal intensity in the left inferior petrosal sinus on arterial MR angiograms could be due to reverse venous flow from the jugular vein toward the cavernous sinus. We later found sluggish flow in the left internal jugular vein and flow-related enhancement, whereas the contralateral jugular vein had a signal void (Fig 4) and contrast-enhanced MR angiograms of the neck in delayed phase showed stenosis in the left brachiocephalic vein of the patient (Fig 5).

Case 2

A 48-year-old woman presented with diplopia. Cranial MR imaging revealed no abnormality. During cranial arterial 3D time-of-flight MR angiography, we noticed abnormally hyperintense vascular signal in the left inferior petrosal sinus and cavernous sinus (Fig 1B). As in the first case, flow direction was cranial, and flow-related enhancement was seen in the left internal jugular vein on T2-weighted MR



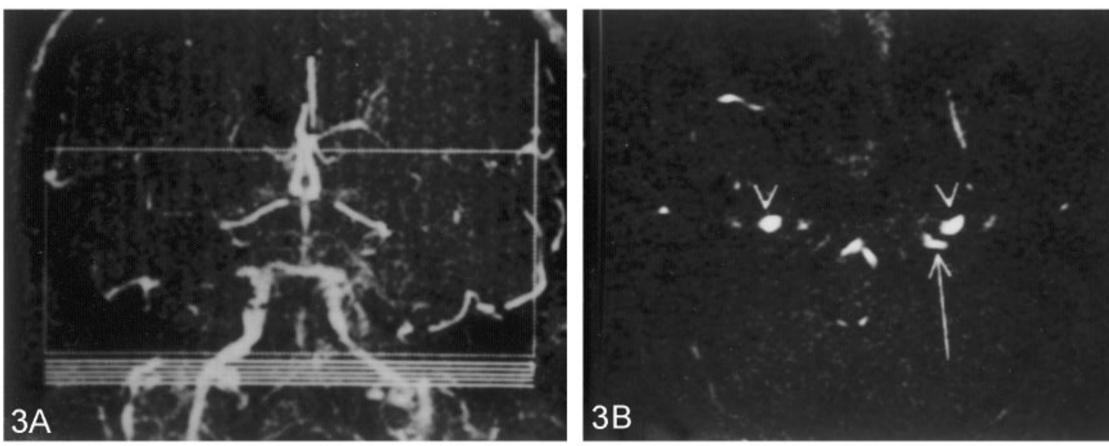


FIG 2. When the flow signal intensity in the inferior petrosal sinus was saturated proximally, the flow signal intensity in the left inferior petrosal sinus was saturated whereas the flow signal intensity in the right inferior petrosal sinus was not.

A, Section (*lines*) and saturation band (*rectangle*) position.

B, Axial view fluid-attenuated fast low angle shot 2D image. Right transverse sinus and right jugular bulb (*arrowheads*) and right inferior petrosal sinus (*arrow*) show bright signal intensity. No vascular signal intensity can be seen in the left inferior petrosal sinus and internal carotid arteries.

FIG 3. When the flow signal intensity in the distal inferior petrosal sinus was saturated, the flow signal intensity in the right inferior petrosal sinus was saturated whereas the flow signal intensity in the left inferior petrosal sinus was not.

A, Section (*lines*) and saturation band (*rectangle*) position.

B, Axial view fast low angle shot 2D image. Bilateral internal carotid arteries (*arrowheads*) and left inferior petrosal sinus (*arrow*) show bright signal intensity.

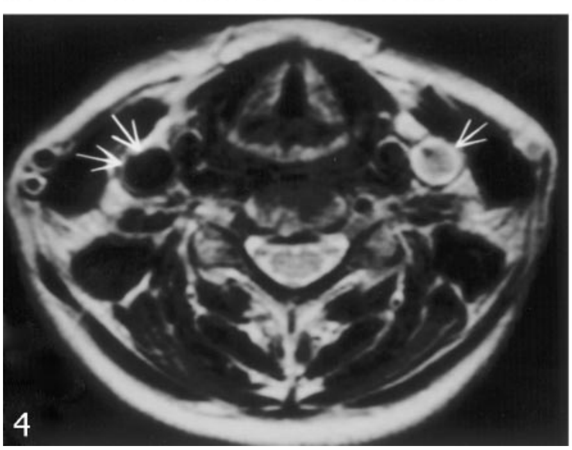


FIG 4. Axial T2-weighted MR image shows normal flow void in the right internal jugular vein (*arrows*), whereas flow-related enhancement can be seen in the left internal jugular (*arrow*) vein due to sluggish flow.

images. Stenosis also was seen in the left brachiocephalic vein, as in the first case.

Case 3

A 70-year-old woman presented with vertebrobasilar insufficiency. In this patient, during cranial arterial 3D time-of-flight MR angiography, we noted abnormally hyperintense vascular signal in the left inferior petrosal sinus and cavernous sinus (Fig 1C). As in the other two cases, flow direction was cranial, and flow-related enhancement was seen in the left internal jugular vein on T2-weighted MR images. Stenosis was also seen in the left brachiocephalic vein, as in the other cases (Fig 5).

After our experiences with the first patients, we did not recommend that the patient undergo digital subtraction angiography for the suspicion of a carotid cavernous fistula. We directly performed central venous contrast-enhanced MR angiography. In the first two patients, no additional pathologic abnormality

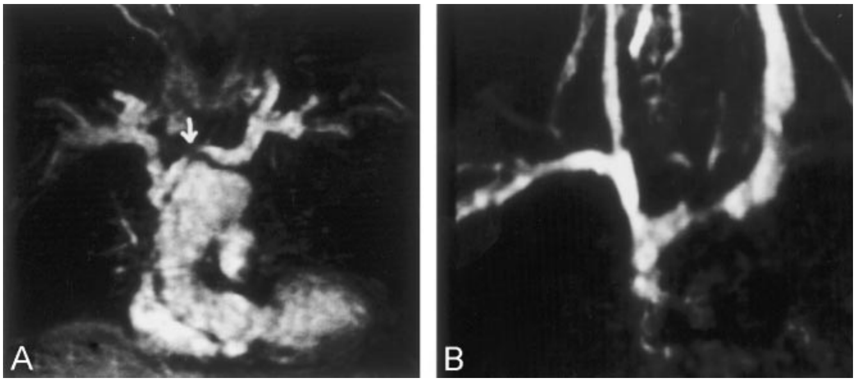


FIG 5. Contrast-enhanced MR angiograms show left brachiocephalic vein stenosis (*arrow*).

A, Before subtraction of the arterial signals (in the third patient).

B, After subtraction of the arterial signals (in the first patient).

was present, but in the third patient, various vertebral artery tortuosity and stenosis could be seen during the arterial phase of contrast-enhanced MR angiography, which could explain the complaints of the patient.

Discussion

The cavernous sinus is a paired venous structure. Its anterior part receives the superior and inferior ophthalmic veins and the sphenoparietal sinus. The posterior part empties into the superior and inferior petrosal sinuses. The inferior petrosal sinus represents the most essential posterior drainage system transporting venous blood from the cavernous sinus toward the jugular bulb. The inferior petrosal sinus frequently can be seen on conventional carotid and vertebral angiograms only by subtraction (6).

3D time-of-flight MR angiography can reveal cavernous sinus vascular pathologic abnormalities. The feeding artery and draining vein in a carotid cavernous fistula can be shown with 3D time-of-flight MR angiography and phase contrast MR angiography (2). In case of pathologic abnormality of the cavernous sinus, abnormal flow-related enhancement of the cavernous sinus with extension into the inferior petrosal sinus should be seen (7). To our knowledge, only one study has been published that illustrates abnormal venous signal intensity in the inferior petrosal sinus and cavernous sinus without carotid cavernous fistula during arterial MR angiography (1).

The source images from MR angiography contain both flow and anatomic information. MR angiograms show isointense signal relative to brain tissue within the cavernous sinus. Because blood flow velocity in a normal cavernous sinus is slow, the blood flow within the structure is saturated and does not show flow-related enhancement. Therefore, hyperintense areas within a cavernous sinus in patients with carotid cavernous fistulas may be considered abnormal (5).

The presence of hyperintense areas within the cavernous sinus on 3D MR angiograms was a more reliable finding than was enlargement of the cavernous sinus on contrast-enhanced CT scans or spin-echo MR images (5). Abnormal flow-related enhancement was found in the left inferior petrosal sinus in our three cases during arterial 3D time-of-flight MR angiography. In the first case, no findings suggested the cavernous fistula, such as distension of the cavernous sinus, enlargement of the superior ophthalmic vein, painful red eye, proptosis, chemosis, or ophthalmoparesis. At first, we considered that the cause of the flow-related enhancement might be a carotid cavernous fistula. However, digital subtraction angiography showed no carotid cavernous fistula. When we saturated the inferior petrosal sinus proximally, flow-related signal intensity in the left inferior petrosal sinus was saturated, whereas signal intensity in the right inferior petrosal sinus was still high. When we saturated the inferior petrosal sinus distally toward the caudal direction, signal intensity suppression occurred in the right inferior petrosal sinus. This time, the left inferior petrosal sinus showed high signal intensity, as in the internal carotid arteries. We considered that the high signal intensity in the left inferior petrosal sinus was due to reverse flow. Flow direction in the transverse and sigmoid sinuses and jugular veins was caudal. We found that flow in the left internal jugular vein was also slow and that stenosis was present in the left brachiocephalic vein. This finding encouraged us to follow the flow direction in the first case. The stenosis in the central vein might cause retrograde flow in the jugular vein, resulting in flow directed contralaterally via the inferior petrosal and cavernous sinuses. However, both the stenosis in the central vein and the sluggish flow in the internal jugular vein suggest that the retrograde flow is due to stenosis. Thus, it may not be surprising to observe a fistula arising from the internal jugular vein toward the cavernous sinus because of venous flow obstruction. As expected, when flow in a vessel is prevented, it initially slows down and then changes direction. It would have been more suitable to see flow velocity and direction in the internal jugular vein and inferior petrosal sinus with phase contrast MR angiography, but a flow quantification optional package was not available with our MR imaging unit.

Ouanounou et al (1) suggested that abnormal cavernous sinus and inferior petrosal sinus signal intensity seen on MR angiograms was due to technical factors. They suggested that abnormal flow enhancement in the cavernous sinus and inferior petrosal sinus was due to the use of higher TR parameters (42 ms). For our three patients, we observed that the use of a lower TR (31 ms) did not result in the loss of abnormal flow-related enhancement on one side. Ouanounou et al reported that visualized flow signal intensity in the cavernous sinus might also be related to the position of the venous structures within the sections selected before examination. In their examination, they used three sections; cavernous and inferior petrosal sinus flow signal intensity was typically identified in the middle section. We observed, in our three cases, that the use of one and two sections in different positions rendered the same results. In the case of Ouanounou et al, abnormal flow-related enhancement occurred on one side only. We think that if abnormal flow-related enhancement had been due to technical factors, it should have been bilateral. We cannot explain one-sided flow-related enhancement with technical factors.

Although identification of normal cavernous or inferior petrosal sinus venous signal intensity on 3D time-of-flight MR angiograms may occur, our results indicate that this also may be the result of anatomic variability contributing to this abnormal venous flow signal intensity in the cavernous and inferior petrosal sinuses. We think that the flow dynamics of the inferior petrosal sinus and internal jugular vein should also be evaluated by using different position saturation bands.

Conclusion

We propose that abnormal flow-related enhancement in the cavernous and inferior petrosal sinuses revealed by arterial 3D time-of-flight MR angiography warrants examination for any evidence of a carotid cavernous fistula or reverse flow due to blood steal arising from the internal jugular vein toward the cavernous sinus. We also suggest that the effects of different MR imaging parameters on signal intensity should be scrutinized. In the presence of any abnormal flow-related enhancement in the inferior petrosal sinus, flow characteristics of the internal jugular veins should also be investigated.

Acknowledgments

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