Original Report

Stephan Meckel[1]
Karl-Olof Lovblad[2]
German Abdo[2]
Diego San Millan Ruiz[2]
Jacqueline Delavelle[2]
Ernst-Wilhelm Radue[1]
Daniel A. Ruefenacht[2]
Stephan G. Wetzel[1]

Arterialization of Cerebral Veins on Dynamic MDCT Angiography: A Possible Sign of a Dural Arteriovenous Fistula

OBJECTIVE. MDCT angiography allows fast imaging of the cerebral vessels, and its potential as a noninvasive technique to detect vascular abnormalities on the basis of morphologic changes is well established. We analyzed vascular enhancement patterns of cerebral venous structures on MDCT angiography, which enabled us to diagnose dural arteriovenous fistula.

CONCLUSION. MDCT angiography performed during an early arterial phase showed asymmetrically higher contrast intensity in the transverse or sigmoid sinus, or both, in five patients. In all patients, digital subtraction angiography confirmed the presence of a dural arteriovenous fistula on the side on which the higher contrast intensity appeared. Radiologists should actively look for this sign in the imaging workup of patients presenting with nonspecific symptoms that might be related to a dural arteriovenous fistula.

Intracranial dural arteriovenous fistulas (DAVFs) account for 10–15% of all intracranial arteriovenous lesions. For detection of these fistulas, digital subtraction angiography is the method of choice, allowing the dynamic assessment of cerebral circulation [1, 2]. Recent advances in MR projection angiography allow the detection and, to a certain extent, the description of the venous drainage of DAVFs. With a 2D dynamic MR angiographic technique, subtraction images can be obtained for dynamic assessment of cerebral arteriovenous flow in a manner similar to that used in the digital subtraction angiographic technique, and early filling of a dural sinus can clearly be depicted [3, 4].

The clinical presentation of DAVF is, however, often variable and nonspecific. Tinnitus and headache are the most common symptoms, but seizures or focal neurologic deficits due to intracranial hemorrhage, for example, can also lead to hospitalization. Other fistulas might be associated with ocular symptoms, with intracranial hypertension, or, if the venous drainage is perimedullary or perispinal, with ascending myelopathy.

Neither digital subtraction angiography nor MRI techniques are usually the primary diagnostic means in the initial workup of patients presenting with headaches, neurologic symptoms, or intracranial hemorrhage; cerebral CT remains the standard imaging technique for fast and reliable detection of acute hemorrhage and vascular diseases. Furthermore, “static” CT angiographic images studied in a 3D mode are well accepted in most centers for depiction of morphologic changes of vasculature and parenchymal vessels [5–7]. However, the new generation of fast MDCT scanners offers the possibility to study alterations in flow dynamics of cerebral perfusion. We report five cases in which MDCT angiography enabled the detection of DAVFs on the basis of dynamic changes in contrast intensity in the cerebral veins.

Received February 26, 2004; accepted after revision July 19, 2004.

Supported in part by Swiss National Science Foundation grant 3200-66634.

[1]Division of Neuroradiology, Department of Radiology, University Hospital Basel, Petersgraben 4, Basel CH-4031, Switzerland. Address correspondence to S. Meckel (meckels@uhbs.ch).

[2]Division of Neuroradiology, Department of Radiology, University Hospital Geneva, Geneva, Switzerland.

AJR 2005;184:1313–1316

0361–803X/05/1844–1313

© American Roentgen Ray Society

Subjects and Methods

Five patients were examined with standard cerebral CT and then with MDCT angiography of the cerebral vasculature. The clinical symptoms and the diagnostic workup in the individual patients are described below. In all patients, intraarterial digital subtraction angiography was performed after MDCT angiography and confirmed the diagnosis of a DAVF. Unenhanced and conventional contrast-enhanced CT was performed on a 4- or 16-MDCT scanner (Mx8000, Philips Medical Systems, or Somatom Sensation 16, Siemens Medical Solutions). The reconstructed slice thicknesses were 10 mm for the supratentorial region and 4.5 mm for the posterior fossa.

MDCT angiography was performed in one patient using a standard protocol for a 4-MDCT scanner: collimation of 1.3 mm (pitch, 1.250), with 0.6-mm reconstruction intervals. Scanning was performed from the centrum ovale continuing downward to the occiput. Five seconds before scanning began, IV injection of 100 mL of nonionic contrast agent was administered at a rate of 4 mL/sec. Other parameters used were 120 kV, 90 mAs, 512 × 512 pixels, and a field of view of 213 mm. The remaining four patients were examined on a 16-MDCT scanner using the following standard protocol: collimation, 0.75 mm; rotation time, 0.5 sec; table feed per rotation, 15 mm (pitch, 1.25); and reconstruction parameters, 0.75 mm with an interval of 0.4 mm. Scanning was performed from the foramen magnum continuing upward to the centrum ovale. Injection of 90 mL of ionic contrast material was started before scanning at a flow rate of 3.5 mL/sec. Bolus tracking was performed with a region of interest placed in the extracranial portion of the internal carotid artery (10-sec monitoring delay). Scanning was initiated 5 sec after the first signs of contrast enhancement had been observed in the region of interest. Other parameters were 120 kV, 100 mAs, 512 × 512 pixels, and a field of view of 200 mm. The source images and multiplanar reconstructions were examined on a PACS workstation. To construct 3D displays, we transferred images to an independent imaging workstation.

Diagnostic intraarterial digital subtraction angiography (matrix size, 1,024 × 1,024; image intensifier, 40 cm) (Multistar TOP, Siemens Medical Solutions, or BV 3000, Philips Medical Systems) was performed after catheterization of the common, external, and internal carotid arteries and of the vertebral arteries with a 4-French catheter via a femoral approach. In selected patients, superselective catheterization of the external branches of the carotid artery was performed.

All examinations were reviewed and discussed by two neuroradiologists. The MDCT angiographic studies were assessed for the presence and location of a DAVF and for signs of reflux into cortical veins. Digital subtraction angiography was the standard of reference. In addition, regions of interest to measure contrast intensities were placed into the transverse and sigmoid sinuses bilaterally on axial MDCT angiographic images, and subtraction of mean values was performed to determine the numeric difference between intensities. These results were compared with findings in five patients without a DAVF. Standard paired two-tailed Student's *t* test analysis was used to assess differences in the contrast intensities of the bilateral sinus structures in both patient groups. A p value of 0.05 or less was considered to indicate a statistically significant difference.

Results

Five patients (three women and two men; mean age, 65.2 years) underwent CT for further diagnostic workup of neurologic symptoms. Four of five presented with headache or localized pulsatile tinnitus or both. In all four patients, noncontrast-enhanced CT findings were normal. A 70-year-old man had an acute onset of confusion and Wernicke's aphasia. He was found to be febrile, and lumbar puncture revealed a slightly elevated level of cerebrospinal fluid proteins (total proteins, 0.68 g/L) but no increased WBC. His CT scan showed a discrete hypodensity in the territory of the middle cerebral artery. Based on the patient's clinical history and these findings, a stroke or early-stage encephalitis was considered to be the most likely diagnosis.

For further evaluation, MDCT angiography was performed in all cases. The key findings identified were local or regional differences in contrast enhancement of the transverse or sigmoid sinus, or both, with higher contrast intensity compared with that of the contralateral venous structures. Thereby, the sinus with higher intensity showed a contrast enhancement similar to that of the depicted cerebral arteries, proving the arterialization of venous structures and suggesting the presence of a fistula (Fig. 1A). In addition, in two patients a prominent temporal vein with high contrast intensity caused by the reflux of arterialized blood into cortical veins (e.g., the vein of Labbé) (Fig. 1B) was noted. All patients proceeded to confirmatory conventional digital subtraction angiography and subsequently to endovascular microcoil occlusion.

Digital subtraction angiography revealed typical findings of a DAVF and allowed the classification of the fistulas according to Cognard et al. [1]. The diagnoses included one patient with a type 1 DAVF (antegrade flow in the sinus), two patients with a type 2a DAVF (retrograde flow in the sinus), and two patients with a type 2b DAVF (retrograde flow with reflux into cortical veins) that had reflux into a temporal vein (Fig. 1C). Digital subtraction angiography allowed detection of the fistula point and the detailed identification of arterial feeders that in all patients involved the occipital artery. In all of the above cases, MDCT angiography allowed detection of a DAVF in the region of the transverse (Fig. 2) or sigmoid sinus (Fig. 1A) on the basis of differences in contrast intensity of venous structures. However, an exact description of venous drainage and location of the fistula and a classification of the fistulas were not possible. Nevertheless, in the two patients with a type 2b DAVF, arterialization of a prominent cortical vein was correctly depicted on MDCT angiography, including in the patient who was initially thought to have ischemic disease in the middle cerebral artery territory.

In the group of patients with a DAVF, mean contrast intensities of 250 H (range, 220–306 H) were measured ipsilateral and of 169.7 H (range, 102–253 H) were measured contralateral relative to the fistula. Patients without a DAVF showed mean intensity values of 157.4 H (range, 96–217 H) in the left sinus versus 155.4 H (range, 108–207 H) in the right sinus. Subtraction of these results yielded the following enhancement differences between bilateral sinus structures: 80.3 H in patients with a DAVF versus 8.4 H in patients without a DAVF. The difference in contrast intensity between transverse or sigmoid sinus on both sides was statistically significant in patients with a DAVF ($p = 0.004$). No significant difference was noted between the left and the right sinus structures in patients without a DAVF ($p = 0.699$).

Discussion

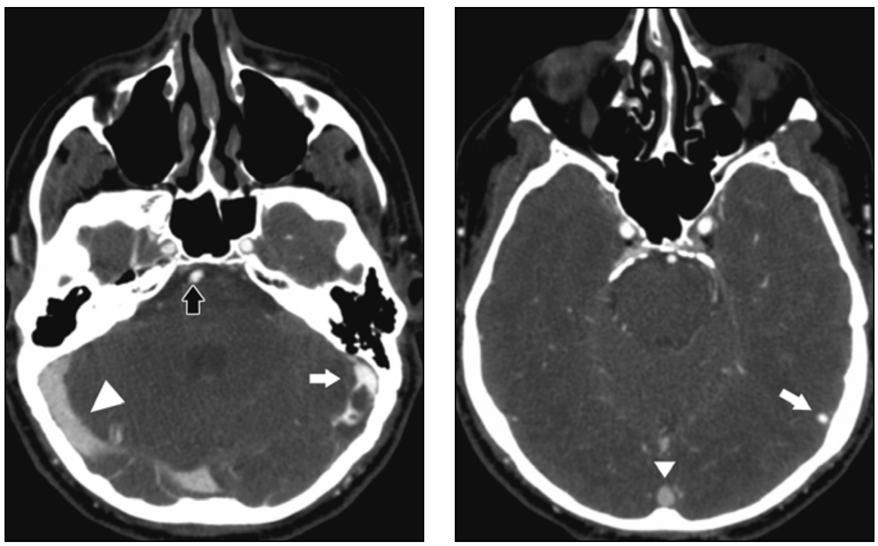
DAVFs are formed by clusters of numerous arteriovenous shunts inside a dural sinus wall consisting of dural arterial feeders and venous drainage [2, 8]. The clinical presentation of a DAVF is quite variable and can be mimicked by a variety of other diseases. Classic symptoms are pulsatile tinnitus, headache, and intracranial bleeding, symptoms related to increased intracranial pressure or infarctions as described in our patients.

For diagnosis and grading of DAVFs, digital subtraction angiography is the method of reference. Because altered flow dynamics might be the main abnormal finding of DAVFs, imaging techniques that do not detect these alterations are of limited value. However, given the high costs and the invasiveness of digital subtraction angiography, on the one hand, and the variety of symptoms of DAVFs on the other, noninvasive methods to diagnose this disease entity are of interest. Conventional contrast-enhanced CT scans, conventional MR images, or even time-of-flight MR angiograms can only hint at the diagnosis of a DAVF in certain cases (e.g., if concomitant morphologic abnormalities such as a nidus in relation to a sinus, venous congestion, or dilated cortical veins are present) [9–11].

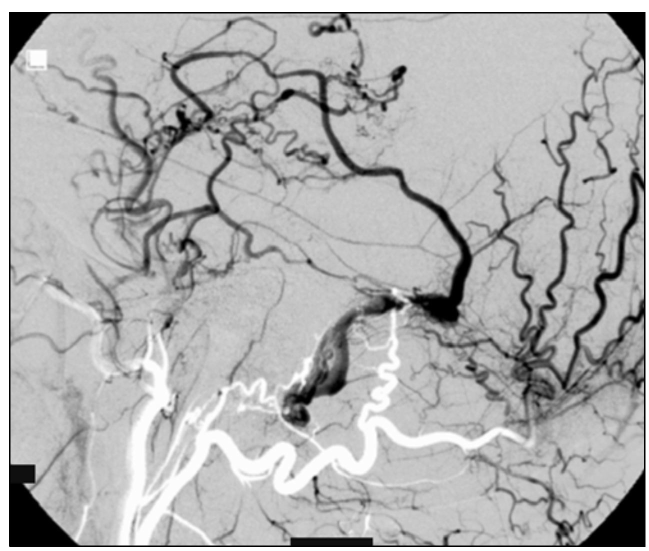
With a contrast-enhanced MR angiographic technique that provides 2D projection images with high temporal and in-plane spatial resolution, we were able to detect DAVFs that were not visualized on other noninvasive imaging techniques [3, 4]. However, the noninvasive alternative with good depiction of changes in venous flow dynamics—namely, MR projection angiography—is not always available at every institution and is often time consuming when performed as the initial emergency workup examination.

It has already been shown that MDCT angiography has a high diagnostic value in imaging the static anatomy of the arterial and venous cerebral circulation [5–7]. However, with the advantage of fast image acquisition, MDCT allows one to obtain multiple slices during a time frame that is short enough to detect even very subtle changes in contrast intensity of cerebral vessels. Using MDCT angiographic scanning that begins during a late arterial phase with low intensity of the venous structures, one can detect arterialized venous blood within the cerebral venous vasculature due to a DAVF draining into a dural sinus. Inspection of the source images using exact and narrow window settings is of high importance in order not to miss subtle differences in contrast intensity between closely related vascular structures within a single layer.

For grading, the direction of the venous drainage is important: If the drainage is antegrade, the clinical course is most often favorable, whereas retrograde flow into the sinus or into cortical veins may cause intracranial hypertension and increase the risk of hemorrhage [1, 8]. The general classification of DAVFs was revised by Cognard et al. [1] to



A B



C

Fig. 1.—70-year-old man with type 2b dural arteriovenous fistula in left sigmoid sinus.
A, Axial CT angiographic (CTA) image shows high-intensity filling in left sigmoid sinus (*white arrow*); note adjacent pacchionian granulation. Contrast intensity is same as that of basilar artery (*black arrow*). Contralateral sinus structures show less intense contrast intensity (*arrowhead*).
B, Axial CTA image obtained at level of cavernous portion of internal carotid artery shows arterial contrast intensity within left vein of Labbé (*arrow*) caused by backflow from fistula. Superior sagittal sinus shows lower venous intensity (*arrowhead*).
C, Cerebral angiogram with external carotid artery injection and mask subtraction clearly shows arterial feeders from occipital artery and reflux into vein of Labbé.

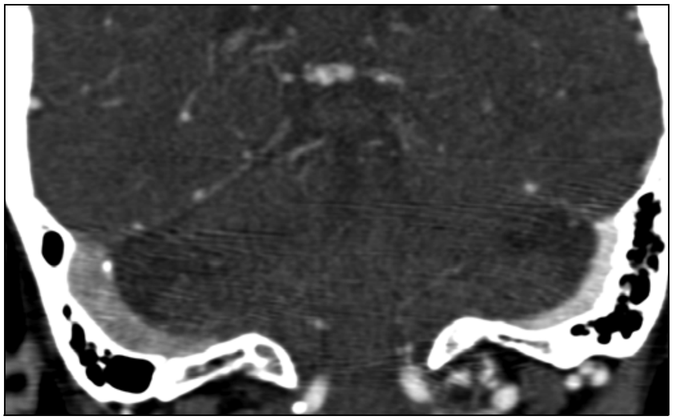


Fig. 2.—77-year-old woman with type 2b dural arteriovenous fistula at junction of left transverse and sigmoid sinuses. Reconstructed coronal CT angiographic image of posterior fossa obtained at level of foramen magnum shows filling of left transverse sinus with high-contrast arterialized blood. Right transverse sinus shows less intense venous contrast filling.

enable prediction of the risk of each DAVF. In our limited experience with a small number of cases, we found on digital subtraction angiography fistulas with antegrade (type 1) or retrograde (type 2a) flow into the dural sinus or reflux into cortical veins (type 2b). It was not possible to classify the venous drainage pattern in detail with the MDCT angiographic technique using the classification refined by Cognard et al. The location of fistula points and the direction of flow within venous sinus structures could not be determined with precision; however, MDCT angiography made it possible to see arterialized temporal veins due to fistula reflux in two patients (Figs. 1A–C).

Evidently, the lack of time-resolved projection imaging in MDCT angiography makes it difficult or impossible to depict the exact anatomy of a DAVF including arterial feeders and the exact site of arteriovenous shunting.

In conclusion, we showed that helical MDCT angiography performed during the arterial phase can reveal the major sign of a DAVF: the arterialization of cerebral veins. We believe that the described feature of asymmetric contrast enhancement in a dural sinus is helpful in an emergency situation and should be looked for actively in any patient presenting with nonspecific or suggestive signs of a DAVF. However, we acknowledge that although in our case series all DAVFs were correctly diagnosed, small or low-flow fistulas may not be detectable and that larger studies are required to determine the sensitivity and specificity of this technique.

References

1. Cognard C, Gobin YP, Pierot L, et al. Cerebral dural arteriovenous fistulas: clinical and angiographic correlation with a revised classification of venous drainage. *Radiology* 1995;194:671–680
2. Newton TH, Cronqvist S. Involvement of dural arteries in intracranial arteriovenous malformations. *Radiology* 1969;93:1071–1078
3. Wetzel SG, Bilecen D, Lyrer P, et al. Cerebral dural arteriovenous fistulas: detection by dynamic MR projection angiography. *AJR* 2000;174:1293–1295
4. Klisch J, Strecker R, Hennig J, Schumacher M. Time-resolved projection MRA: clinical applications in intracranial vascular malformations. *Neuroradiology* 2000;42:104–107
5. Alberico RA, Patel M, Casey S, et al. Cerebral aneurysms: evaluation with three-dimensional CT angiography. *Am J Neuroradiol* 1995;16:1571–1578
6. Klingebiel R, Busch M, Bohner G, Zimmer C, Hoffmann O, Masuhr F. Multi-slice CT angiography in the evaluation of patients with acute cerebrovascular disease: a promising new diagnostic tool. *J Neurol* 2002;249:43–49
7. Casey SO, Alberico RA, Patel M, et al. Cerebral CT venography. *Radiology* 1996;198:163–170
8. Chung SJ, Kim JS, Kim JC, et al. Intracranial dural arteriovenous fistulas: analysis of 60 patients. *Cerebrovasc Dis* 2002;13:79–88
9. Willinsky R, Terbrugge K, Montanera W, Mikulis D, Wallace MC. Venous congestion: a MR finding in dural arteriovenous malformations with cortical venous drainage. *Am J Neuroradiol* 1994; 15:1501–1507
10. De Marco JK, Dillon WP, Halbach VV, Tsuruda JS. Dural arteriovenous fistulas: evaluation with MR imaging. *Radiology* 1990;175:193–199
11. Chen JC, Tsuruda JS, Halbach VV. Suspected dural arteriovenous fistula: results with screening MR angiography in seven patients. *Radiology* 1992;183:265–271