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Regional association of developmental venous anomalies with angiographically occult vascular malformations

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Abstract. This study reviews the neuroradiological findings of 43 patients with a developmental venous anomaly in order to discuss the clinical significance of this entity. All patients underwent unenhanced and contrast-enhanced computer tomography and magnetic resonance tomography, as well as selective angiography, and were followed for at least 2 years. In 40 % (17 of 43) of patients a cryptic vascular malformation was found in the proximity to the developmental venous anomaly. Neurological symptoms were present in 8 of 17 patients (47 %) in this group. Patients with an isolated developmental venous anomaly had symptoms in 19 % (5 of 26), but none of them had experienced a hemorrhage. Magnetic resonance was the most sensitive method for the diagnosis of both types of lesions and alterations of the adjacent parenchyma. These results further support that developmental venous anomalies represent a clinically benign entity. However, patients with an association of a developmental venous anomaly and a cryptic vascular malformation are at risk for hemorrhage from their angiographically occult vascular malformation. Magnetic resonance proved to be the imaging modality of choice for both entities and is appropriate for diagnosis and follow-up.

Key words: Venous angioma – Developmental venous anomaly – Magnetic resonance – Cavernoma – Cerebral veins – Cryptic vascular malformations – Angiographically occult vascular malformations

Introduction

The term "cerebral venous angioma," often used in the angiographic literature [1–3], has provoked controversial discussions. The entity consists of fine medullary veins without smooth muscle or elastic fibers, which are interspersed in normal neural tissue and converge into a single and often dilated vein, leading to the characteristic caput medusae-like appearance [4–7]. The drainage is directed to the cortical veins and less frequently (20 %) to deep subependymal veins and the galenic system. A combination of both patterns is found in up to 10 % of cases [8]. A deep drainage is reported more frequently in the posterior fossa [9]. Venous angiomas are common congenital intracranial vascular abnormalities (0.25 %) and are presently better referred to as *developmental venous anomalies* (DVAs) [10]. They occur in the frontal (36–56 %), parietal (12–24 %), occipital (4 %), and the temporal lobes (2–19 %), in the cerebellum (14–29 %), the basal ganglia (6 %), the thalamus, the ventricles (11 %), and, rarely, in the brain stem [6, 8, 31]. The DVAs may be multiple in as much as 25 % [11]. Their association with a sinus pericranii [9] or a cerebral varix [12] has been described.

Unenhanced computer tomography (CT) is usually normal and contrast-enhanced CT may show a DVA as an enhancing linear or curvilinear structure in the white matter without mass effect or surrounding edema [8, 13]. Magnetic resonance imaging (MRI) shows DVAs either with low signal intensity (SI) due to flow void [6, 14] or high SI due to slow-flow rephasing. Rarely, an altered SI of the surrounding parenchyma is found [15]. Gd-DTPA-enhanced MRI and MR angiography have proven to be superior in the visualization of DVAs [16].

It is still controversially discussed whether DVAs may cause intracranial hemorrhage and neurological deficits. Most often, DVAs represent a functionally intact but dysplastic vascular pattern [9]. However, a DVA may be associated with other vascular malformations [17], especially cavernomas, that carry the risk of hemorrhage.

Here we report on the neuroradiological findings of 43 patients bearing a DVA and place special emphasis on the pathophysiological significance of those DVAs that were associated with angiographically occult vascular malformations (AOVMs).

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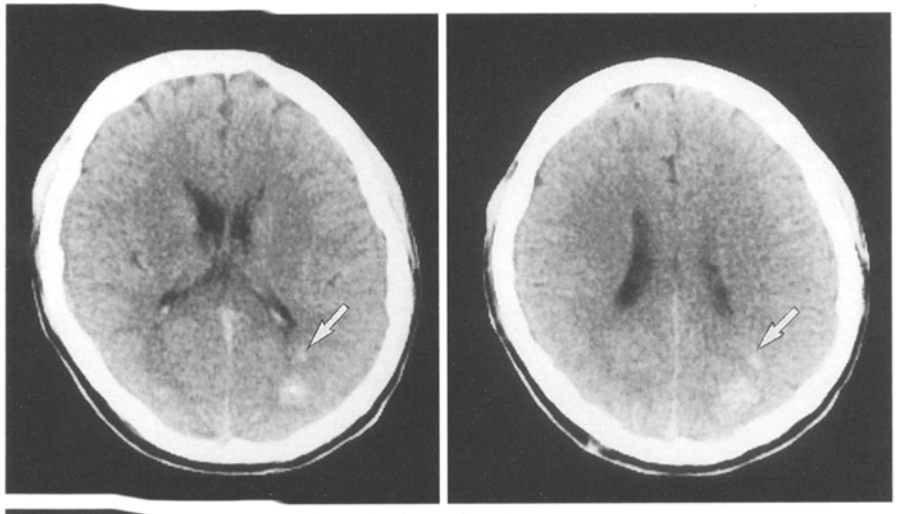
Fig. 1 a–d. Association of a developmental venous anomaly (DVA) and an angiographically occult vascular malformation (AOVM) in the left occipital lobe of a patient (no. 15) who had suffered a single grand mal seizure within 6 years. **a** The contrast-enhanced CT scans show a nodular hyperdense lesion in the parieto-occipital region on the left. A faintly hyperdense focus adjacent to the posterior horn of the lateral ventricle is a part of the DVA *(arrows)*. **b** Angiography demonstrates the fine medullary veins and the enlarged, transparenchymally collecting vein *(arrow)* of the DVA, but fails to visualize the AOVM. The venous system appears dysplastic. **c** The T2-weighted MR images show the AOVM with a hyperintense center, surrounded by the typical rim of signal void due to hemosiderine *(curved arrow)*. The DVA is partially shown as a hyperintense tubular structure. **d** The DVA becomes clearly visible on the T1-weighted image after the administration of Gd-DTPA and correlates well with conventional angiography. There is also a faint contrast enhancement of a AOVM *(curved arrow)*. (For imaging parameters see text)



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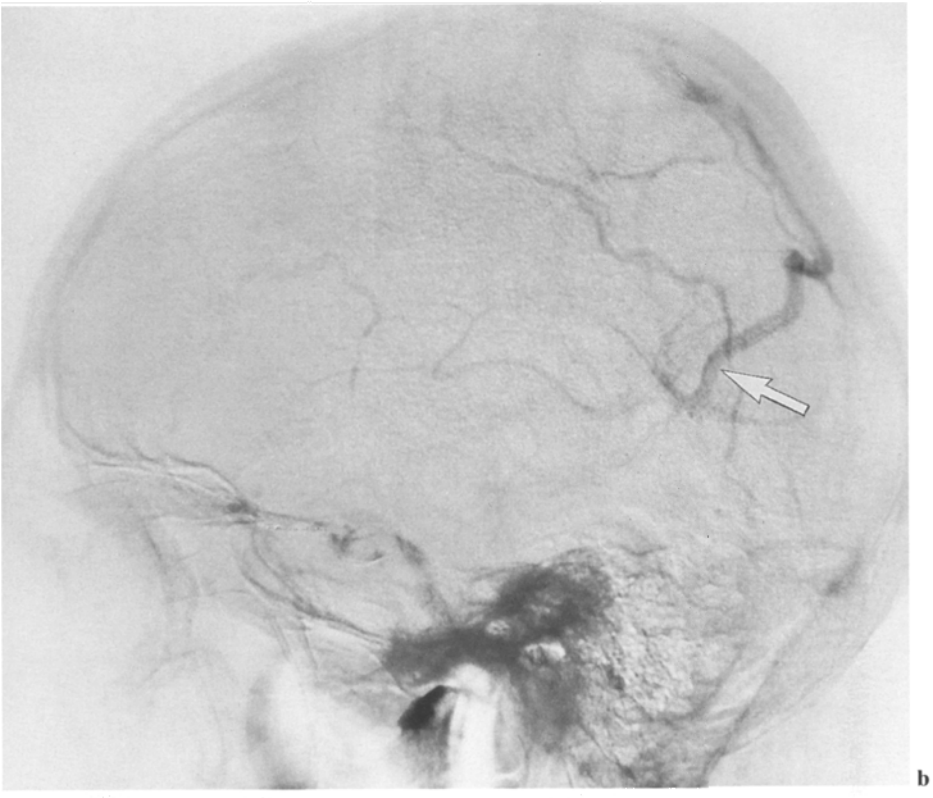

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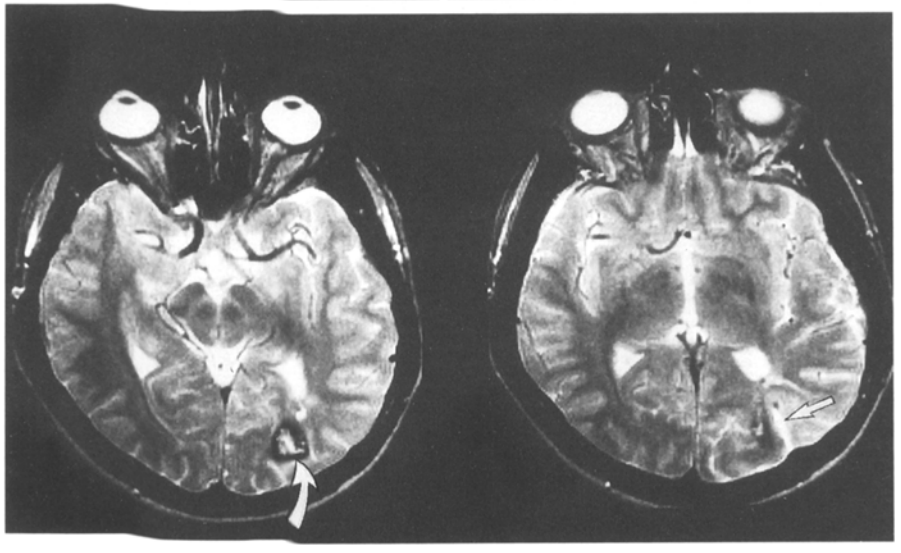

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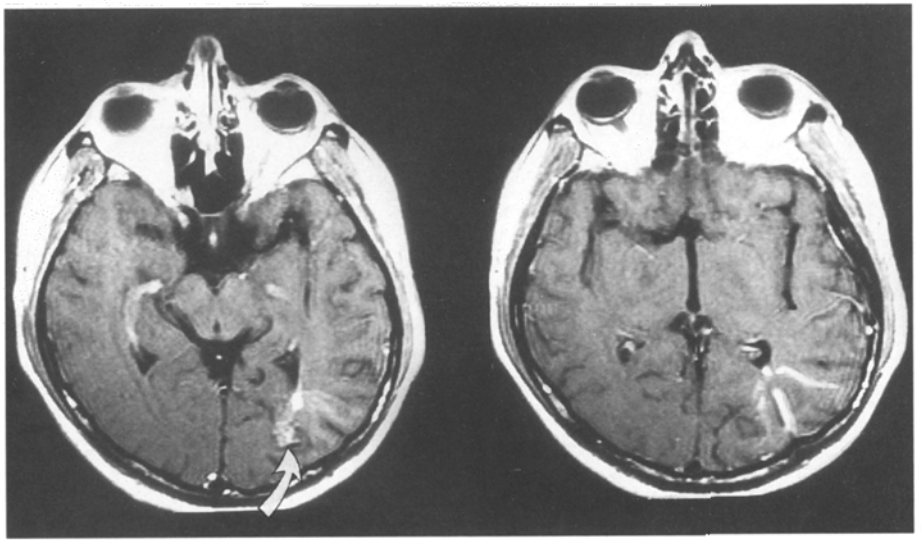

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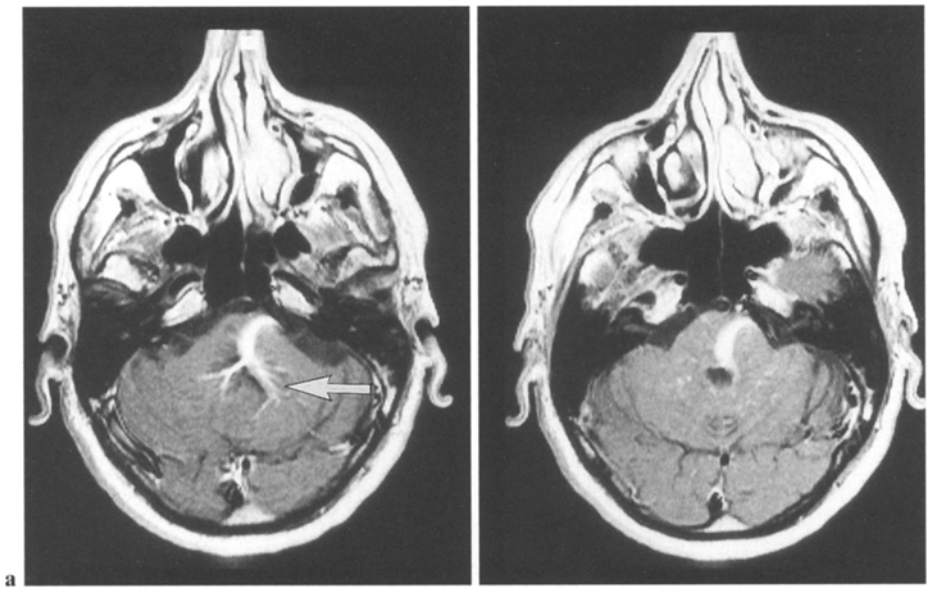
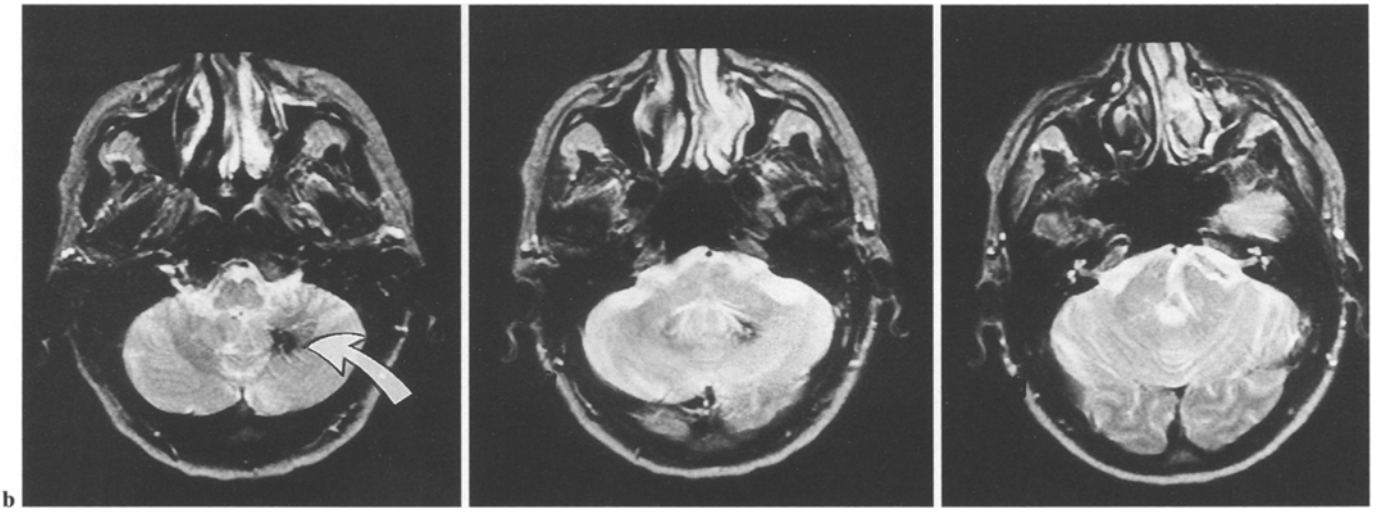


Fig. 2a, b. Association of a bilateral cerebellar DVA with an AOVM of the left cerebellar hemisphere in a patient (no. 17) without neurological symptoms. **a** The T1-weighted MR after application of Gd-DTPA reveals the draining veins of the DVA *(arrow)* converging into a large transpontine vein. **b** On the T2-weighted MR scans the draining veins appears with high signal intensity, due to slow-flow rephasing. In addition, the T2-weighted image shows an AOVM with typical signal void due to hemosiderine in the left cerebellar hemisphere *(curved arrow)*, which was not depicted on CT and T1-weighted MR images. (For imaging parameters see text)



Patients and methods

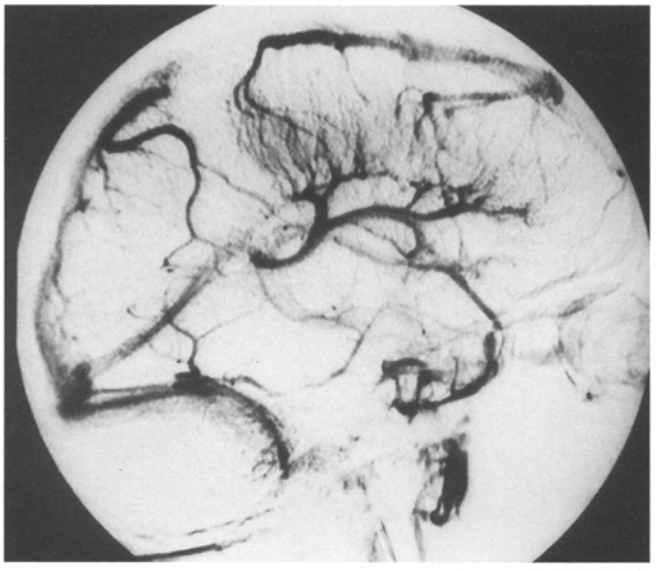
This study comprises 43 patients with a DVA first diagnosed in the period from 1982 to 1992. The patients were regularly followed over 2–10 years. There were 25 males and 18 females, 5–66 years (mean 31 years) of age. All patients underwent angiography, CT, and MR at least once during the observation period. The clinical records and the imaging results were independently analyzed.

Selective transfemoral catheter angiography included a series of 15 s or more and subtracted images were obtained by film- or digital subtraction using a 1024×1024 matrix (Polytron, Siemens, Erlangen, Germany). In every patient at least the carotid and vertebral artery ipsilateral to the DVA and AOVM were injected, although most patients had a complete four-vessel angiography.

The CT examinations were carried out on a third-generation scanner (Somatom DRG, Siemens, Erlangen, Germany). All patients underwent single or repeated scanning involving unenhanced as well as con-

Fig. 3a–c. A DVA associated with multiple AOVMs (patient 11). **a** During the venous phase of the left ICA angiogram a large DVA draining the frontal lobe becomes visible. **b** The Gd-DTPA-enhanced T1-weighted image reveals hyperintense foci of the caudate nucleus and the putamen, typical of cavernomas *(curved arrows)*. **c** The T2-weighted image at a higher level reveals an additional hypointense focus in the frontal lobe suggesting a third cavernoma *(curved arrow)*. (For imaging parameters see text)

Fig. 4a–c. A coarse calcification (AOVM) adjacent to a DVA (patient 14). **a** The unenhanced CT shows a spherical calcification near the frontal horn of the left ventricle *(curved arrow)*. **b** On contrast-enhanced T1-weighted images the calcification (AOVM) appears homogeneously hyperintense *(curved arrow)*, surrounded by a rim of signal void and the presence of an adjacent DVA *(arrows)*. **c** The calcification and hemosiderin depositions are represented by an area of signal void *(curved arrow)* on T2-weighted images. (For images parameters see text)



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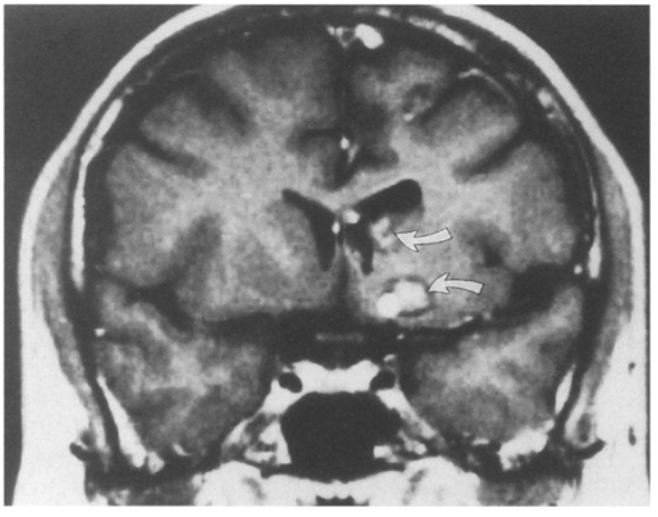

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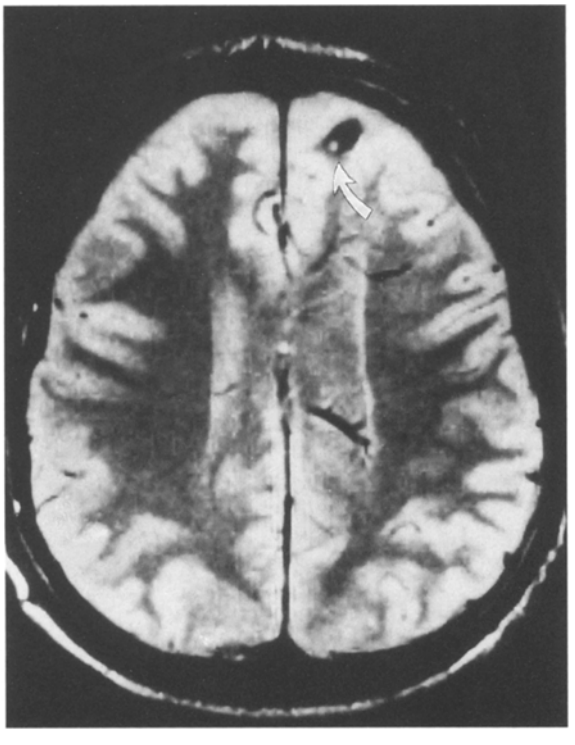

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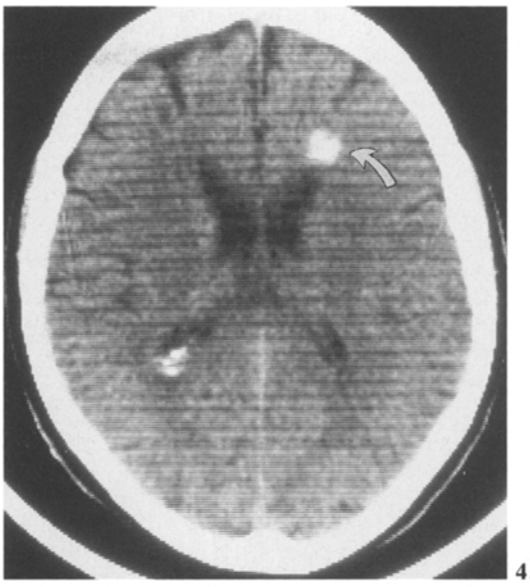

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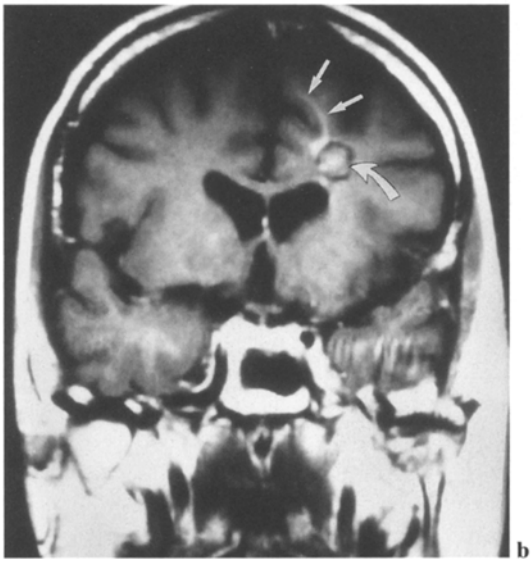

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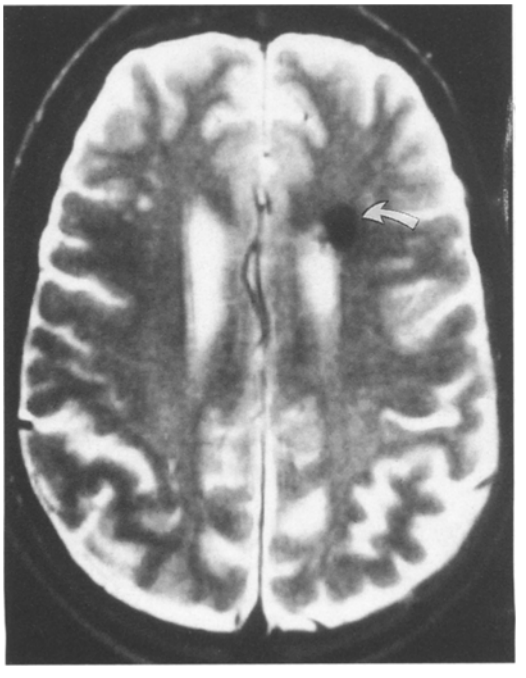

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Table 1. Location of an intracranial developmental venous anomaly (DVA) associated with an angiographically occult vascular malformation (AOVM) and clinical signs and symptoms in 17 patients

Patient No.	Age[a]/gender	Location/side	Symptoms at diagnosis	Acute hemorrhage	Extracerebral manifestations
1	26M	Basal ganglia R			
2	13F	Frontal L	Hemiparesis		
3	37F	Frontal R			
4	14M	Frontal R	Hemiparesis		Cutaneous Hemangioma
5	29F	Frontal L	Aphasia	+	
6	54M	Frontal L			Klippel-Trenaunay Syndrome
7	38M	Cerebellar R	Nystagmus		
8	23F	Parietal R	Seizures	+	
9	39M	Basal ganglia L			
10	8M	Cerebellar L			
11	11F	Frontal L	Seizures		
12	29M	Frontal L			
13	61M	Frontal L			
14	9M	Temporal R			
15	40M	Occipital L	Seizures		
16	49M	Basal ganglia R	Hemiparesis	+	
17	53M	Cerebellar L + R			

[a] Age range 8-61 years; mean 29 years

trast-enhanced studies. Contrast enhancement was achieved by rapid-drip infusion of a nonionic iodinated contrast medium (Omnipaque 300, Schering AG, Berlin, Germany). The image matrix was 256 × 256 and the slice thickness was 4 or 8 mm.

The MR examinations were performed on a 1-T superconducting system (Magnetom 42, Siemens, Erlangen, Germany). Precontrast T1-weighted images were generated by a spin-echo sequence: 600/15/2 (TR/TE/excitations), proton-density-weighted images were acquired with 2200/25/1 and T2-weighted images with 2200/90/1. Gadolinium-DTPA was administered intravenously at a dose of 0.1 mmol/kg body weight (Magnevist, Schering, Berlin, Germany). The T1-weighted sequence was repeated in the axial and coronal plane within 5 min after contrast medium injection. The slice thickness was 7 mm with a 2.5-mm gap. At a 20-cm field of view, a matrix of 256 × 192 was employed.

Results

The diagnosis of a DVA was proven by angiography in all patients. A total of 17 patients had an association of a DVA with an AOVM. In 11 of 17 cases the DVA was of the superficially draining type, and in 6 of 17 cases it was of the deeply draining type. The location of the DVA and the adjacent AOVM was frontal in 8 of 17, parietal in 1 of 17, occipital in 1 of 17, temporal in 1 of 17, and cerebellar in 3 of 17 patients. In 3 of 17 patients the combined DVA/AOVM were in the basal ganglia. All DVAs had a typical appearance on angiography and the AOVMs diagnosed by MRI and CT.

Contrast-enhanced CT scans showed the medullary veins and the collecting vein depending on the location of the DVA and the slice orientation relative to its course. Based on unenhanced and contrast enhanced CT scans the DVA was definitely identified in 13 of 17 patients.

Magnetic resonance was superior to CT due to superior soft tissue contrast and multiplanar capability. Contrast enhanced T1WIs demonstrated the DVA in all patients and delineated the extention more accurately than contrast enhanced CT scans (Figs. 1, 4 and 5). T2WIs were best suited to demonstrate the adjacent AOVM (Figs. 1–5). The AOVM appeared as an area of circumscribed signal void in 4 of 17 patients. Mixed signal intensities surrounded by a hypointense rim were found in 13 of 17 patients. The AOVM showed contrast enhancement in 5 patients, 2 of whom also had positive contrast enhancement on CT. Subacute hemorrhage with typical methemoglobine signal was recognized in 3 patients. Multiple AOVMs were found in 1 patient (Fig. 3), and another patient had a cutaneous hemangioma of the left hemipelvis. Bilateral hypertrophy of the legs was seen in a patient with Klippel-Trenaunay syndrome.

The evaluation of CT showed focal calcifications of various degrees in all patients with a AOVM. Hyperdensity on CT corresponded to signal void on T2-weighted MR scans (Fig. 4). Focal brain atrophy was seen in 10 of 17 patients in the region of the AOVM (Fig. 5).

The evaluation of neurological symptoms was performed with regard to the location of the vascular malformation. In the subgroup of 17 patients with a combined DVA and AOVM 8 (47%) experienced focal neurological symptoms or seizures during the observation period. Of them, 6 had evidence of previous hemorrhage and all had focal calcifications, and 6 also had focal brain atrophy. Signs of calcifications without focal symptoms were seen in another 6 patients (Table 1).

Among the 26 patients with an isolated DVA, 2 presented with recurrent headache. One patient had experienced a single grand mal seizure. Another patient complained of a transient sensory deficit and one had had a short-lasting episode of aphasia. None of them had neuroradiological evidence of intracranial hemorrhage. In the remaining patients the DVA was an incidental finding.

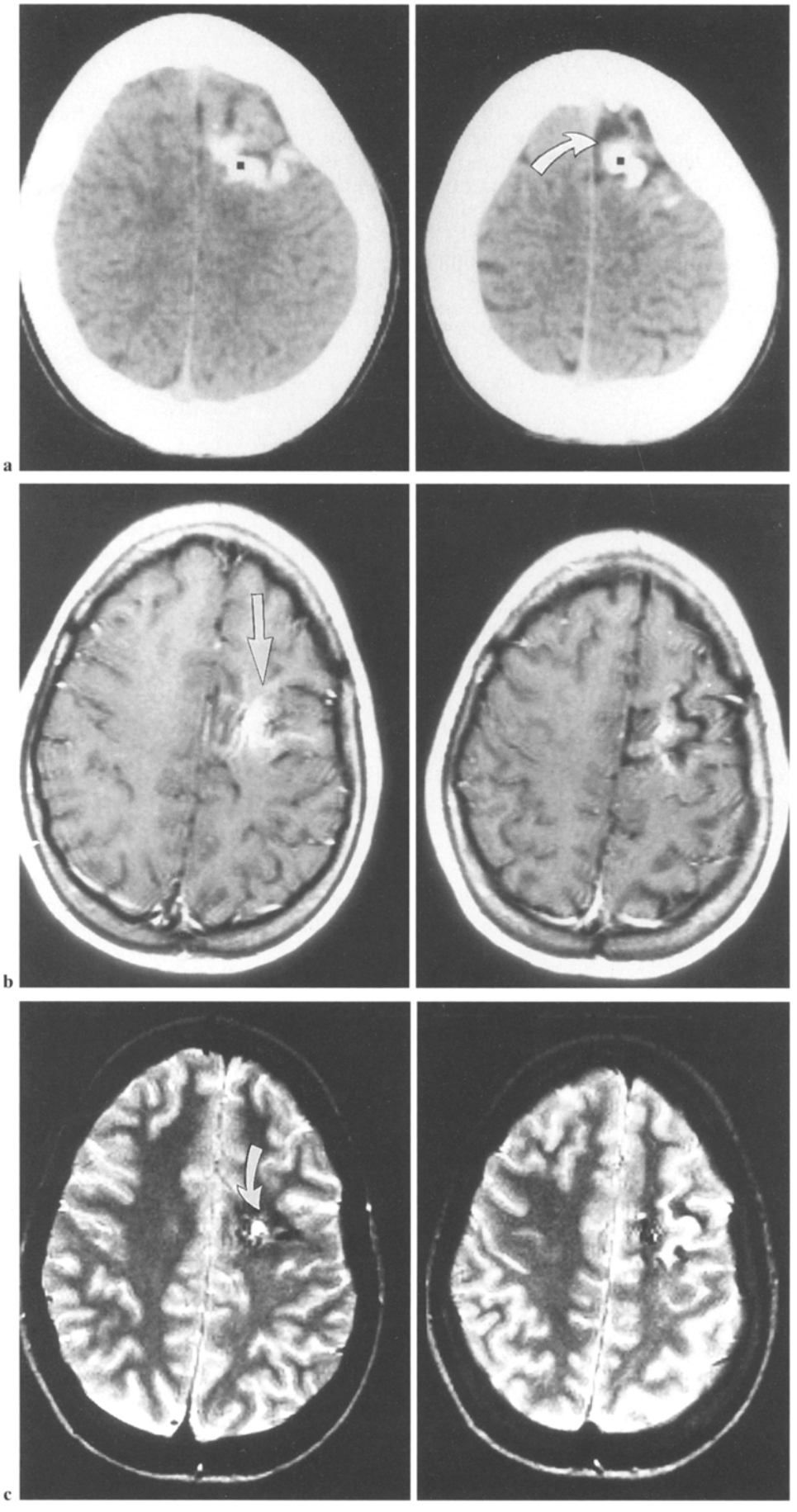

Fig. 5 a–c. Focal cortical brain atrophy adjacent to a DVA associated with an AOVM (patient 2). **a** The unenhanced CT shows coarse calcifications *(black cursor)* and a cortical defect *(curved arrow)*. **b** The caput medusae of the DVA is clearly depicted *(arrow)* on Gd-DTPA T1-weighted images. **c** On T2-weighted images hyperintensities can be attributed to the cortical defect, to the DVA, and to parts of the AOVM. Other parts of the AOVM and calcified areas appear hypointense *(curved arrow)*. (For imaging parameters see text)

Discussion

The embryogenesis of DVAs is considered to result from an insult during Padget's fourth to seventh stage leading to a circumscribed occlusion or maldevelopment of the normal venous drainage. The drainage is either taken over by dilated medullary veins, which converge to an enlarged transcerebral collecting vein [18], or by a persistence of intrinsic venous anastomoses. Both explanations lead to the typical appearance of a DVA. The fact that the neural tissues adjacent to a DVA most often do not exhibit any morphological or functional abnormalities argues against this theory [10], and the association of DVA with AOVM indicates a common or at least a similar pathogenesis. This is further supported by the observation that AOVMs are commonly associated with anatomical variations of the venous system [19].

It is well documented that AOVMs are a cause of seizures, neurological deficits, and hemorrhage [20–22]. In contrast, the clinical relevance of DVAs remains unclear. Most authors consider them as clinically benign [11, 18], whereas others consider that a DVA may carry the risk of bleeding, seizures, or focal neurological deficits [17, 23–28]. Burke et al. [30] reviewed 53 patients with a DVA published between 1968 and 1983 and found hemorrhages in 19 % and seizures in 26 %. Garner et al. [31] reviewed 100 patients with a DVA and found a potential relationship of the DVAs with headaches (4 %), seizures (5 %), neurological deficits (8 %), and intracranial hemorrhage (1 %). Wilms et al. [32], noted signs of previous hemorrhage on the MR scans of 4 of 28 patients with a DVA. Cranial nerve symptoms [4, 9] and hydrocephalus [33] may rarely occur due to compression by enlarged draining veins. In our series DVAs were associated with unspecific headache in 2 patients, transient focal symptoms in 2 patients, and 1 patient had experienced a seizure. Neurological symptoms caused by a DVA may be referred to altered local microcirculation and thombosis of the collecting vein [10]. The clinical symptoms of the patients in our series were either minor or transient, and none of them had intracranial hemorrhage. These results further underline that a DVA represents a clinically benign entity. The higher incidence of hemorrhage in the DVA literature up to 1983 [30] as compared with later studies [31] and our results may be explained by the difficulties to identify an adjacent AOVM to a DVA in the pre-MR era.

The diagnosis of AOVM was a problem until MRI became available. This is reflected by descriptions of DVAs as nodular areas of increased density [23] or nodular enhancement [33] on CT, which might in fact have been signs of an associated AOVM. In addition, the presence of a mixed or transitional vascular malformation must be considered [34]. Previous hemorrhage may itself have destroyed an AOVM, or, in cases with massive hemorrhage, a small AOVM may remain undetected even at neuropathological examination [1].

In our study of 43 patients with an angiographically proven DVA, MRI disclosed an associated AOVM in 17 of them (40 %). An association of a DVA with an AOVM has previously been in reported 8 % [11] to 27 % [9] of patients bearing a DVA. The higher incidence of DVAs associated with an AOVM in our study can be explained by the fact that all patients underwent MRI. The MR appearance of the AOVM was highly characteristic in 13 patients, where iso- or hyperdense spherical lesion was surrounded by a hypointense rim (Fig. 1 a). In four patients MR showed a circumscribed signal void (Fig. 4), which appeared hyperdense on unenhanced CT. Although none of our patients required surgery and the types of the AOVMs could not be further specified, the MRI appearance was strongly suggestive of a cavernoma in 13 of the patients. Perifocal tissue alterations were detected in 16 of 17 patients, but only 8 were symptomatic.

Of the patients with a DVA associated with an AOVM, 47 % (8 of 17) had neurological symptoms (Table 1). Three patients had suffered apoplectiform clinical deterioration and neuroradiological evidence of circumscribed hemorrhage, but focal neurological deficit rapidly improved or was minor, and surgery was not indicated. Because DVAs and AOVMs were located close to each other, a potential contribution of the DVA to the pathogenesis of the symptoms had to be considered. The fact that all patients with a combination of a DVA with an AOVM had the presence of hemosiderine deposition on T2-weighted MRI scans, whereas none of the patients with a single DVA had such a finding, strongly suggests a causative role of the AOVM for focal neurological symptoms and deficit. Such hemosiderine depositions were present in all patients with DVA and associated AOVM, regardless of clinical episodes suggesting hemorrhage. These findings underline the importance of clinically silent macro- and microscopic hemorrhage from an AOVM.

The synoptic evaluation of the applied neuroradiological techniques revealed that MR is the imaging modality of choice for the diagnosis of DVAs and AOVM. The direct visualization of an AOVM on MR is predominantly based on the high sensitivity to local magnetic field inhomogeneities, which may be induced by hemosiderine and calcifications. Contrast-enhanced T1-weighted images were superior for the visualization of DVAs. The future role of MR angiography remains to be evaluated.

Based on imaging findings it is not always possible to classify an AOVM according to neuropathological criteria. However, this may not be a prerequisite for clinical management. Surgical resection of a DVA has been reported [4], although DVAs represent functionally intact structures. The resection of the collecting vein of a DVA can compromise the venous drainage of the involved brain and lead to infarction [5, 11, 35]. On the other hand, symptomatic AOVMs should be resected when surgically accessible, because these carry the risk of parenchymal hemorrhage [20, 34]. In patients with a DVA in association with an AOVM or an AVM, removal of the latter and the preservation of the DVA is the appropriate procedure [36].

In conclusion, up to 40 % of cerebral DVAs may be associated with an AOVM in the same anatomical re-

gion of the brain. Most often DVAs are an incidental finding without relationship to neurological symptoms. In our series 19 % of these patients had symptoms, but without evidence of hemorrhage. In contrast, almost 50 % of the patients with a combination of DVA and AOVM had focal neurological symptoms or seizures attributed to previous macro- or microhemorrhage into the AOVM. Magnetic resonance is the imaging modality of choice to diagnose both types of lesions, and angiography is dispensable in those patients with DVA but without signs of previous hemorrhage. On the other hand, MRI is essential in patients diagnosed to bear a DVA on angiography or CT to rule out an associated AOVM.

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