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Arachnoid Granulations in the Transverse and Sigmoid Sinuses: CT, MR, and MR Angiographic Appearance of a Normal Anatomic Variation

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PURPOSE: To investigate the imaging characteristics, prevalence, and clinical significance of arachnoid granulations in the transverse and sigmoid venous sinuses. **METHODS:** We reviewed the imaging findings, clinical signs and symptoms, final diagnoses, and follow-up studies of 32 patients with 41 probable arachnoid granulations. **RESULTS:** On CT scans, arachnoid granulations appear as well-defined filling defects, wholly or partly within a venous sinus, with the same density as cerebrospinal fluid. MR images show these entities as largely isointense with cerebrospinal fluid in all sequences. Linear variations of signal intensity within the granulations are thought to be fibrous septa or vessels. Calcification was present in 3 granulations and altered both CT density and MR signal intensity. The granulations appear as filling defects at MR angiography and at digital subtraction angiography. In some oblique MR angiographic projections, they appear elliptical and could be mistaken for thrombus. No clinical significance could be given to the existence of any of these arachnoid granulations. They occur in 0.3 to 1 of 100 adults in the population. **CONCLUSION:** Arachnoid granulations in the transverse and sigmoid venous sinuses are common findings seen with thin-section imaging and are usually of no significance.

Index terms: Arachnoid, anatomy; Dural sinuses

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Over the last 5 years we collected imaging studies obtained with computed tomography (CT), magnetic resonance (MR) imaging, MR angiography, and digital subtraction angiography in which filling defects were seen within the transverse or sigmoid venous sinuses. We consider these to be arachnoid granulations protruding into the sinuses, an observation that is supported by Tokiguchi et al (1) in a report containing autopsy proof and by Mamourian and Towfighi (2). We suggest that these granulations are common, normal variants. We describe the appearance of these structures on imaging studies and review the clinical signs and symptoms in 32 patients.

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Materials and Methods

Over a 5-year period we collected all imaging studies that showed any possible arachnoid granulations in the transverse or sigmoid sinuses. Because most of these lesions seem to be clinically innocent, additional or follow-up CT, MR imaging, or digital subtraction angiography was not indicated; however, three patients volunteered to have MR imaging in addition to their original CT examinations. Various CT scanners were used; MR images were obtained primarily on a 1.5-T superconducting magnet; and digital subtraction angiography was performed with modern 1024-matrix units. All studies were reviewed to record the site and number of granulations, their apparent internal morphology, any adjacent veins, and their effect on adjacent bone.

For all patients, we conducted clinical interviews (with follow-up periods ranging from 3 months to 5.5 years) in which the signs and symptoms leading to the initial examination, the final diagnosis, and the current states of health were recorded. These interviews were conducted with the referring specialist, with the general practitioner, or, occa-

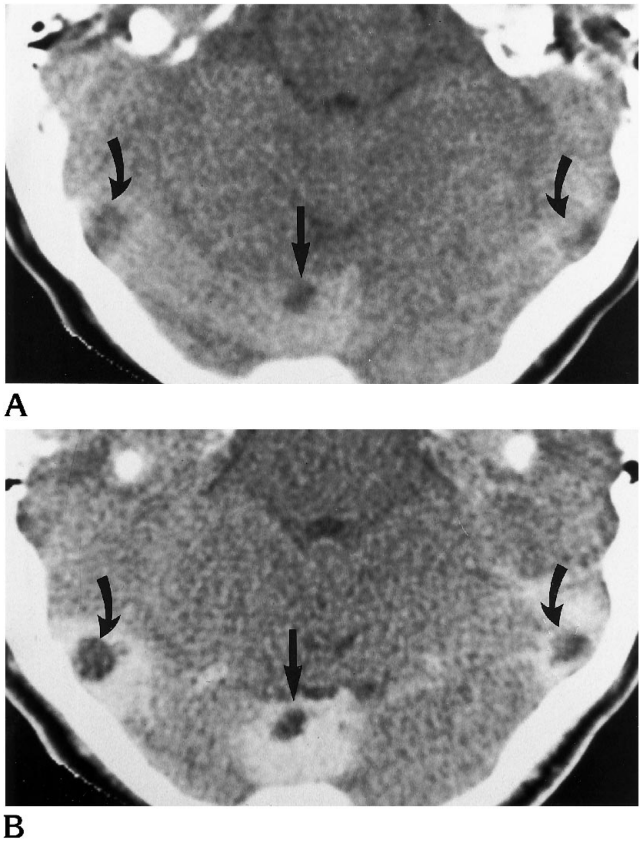

Fig 1. Precontrast (*A*) and postcontrast (*B*) axial CT scans show three granulations, one in the lateral third of the transverse sinus on each side and one at the torcular (*arrows*).

sionally, with the patients themselves. No biopsy, surgical, or autopsy confirmation is available for these patients.

Results

Seventeen men and 15 women, 20 to 75 years old, were found to have 41 arachnoid granulations. One patient had 3 granulations (Fig 1) and 7 patients had 2 granulations. Multiple granulations were usually located at similar sites on opposite sides, but occasionally they were adjacent to one another (Fig 2). The most common location was the middle third of the transverse sinus, with 21 granulations; the next most common location was the lateral transverse sinus, with 14 granulations (Fig 3). Two granulations were seen at the confluence of the sinuses, 3 were seen in the superior portion of the sigmoid sinus, and 1 was seen in the middle portion of the sigmoid sinus. The granulations were oval or round, with a diameter that ranged from 3 to 14 mm. Only 2 granulations were larger than 10 mm. Their average size was 7 mm; 7 were between 3 and 5 mm, 20 were between 6 and 8 mm, and 9 were larger than 8 mm. Measurements were not possible for 5 granulations.

CT scans were available for 26 patients with 31 granulations. Granulations were best appreciated on thin-section scans obtained after intravenous administration of contrast material, and all were visible on the 25 postcontrast studies available. In 6 of the 17 noncontrast studies available, the granulations were not visible. This was most probably because the section thickness and levels were not identical with the postcontrast studies. The density of most granulations was nearly equivalent to cerebrospinal

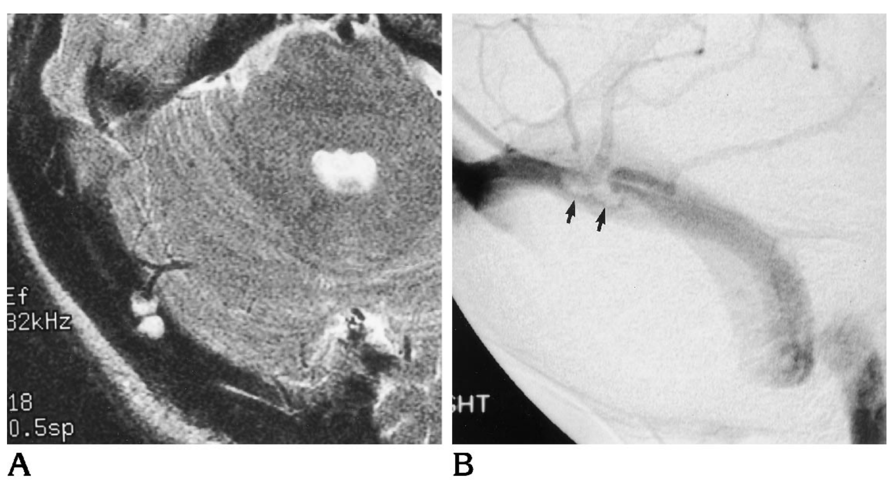

Fig 2. Axial T2-weighted MR image (*A*) and lateral digital subtraction angiogram, venous phase (*B*), show a double granulation (*arrows*) in the right transverse sinus with vein draining into the anterior granulation.

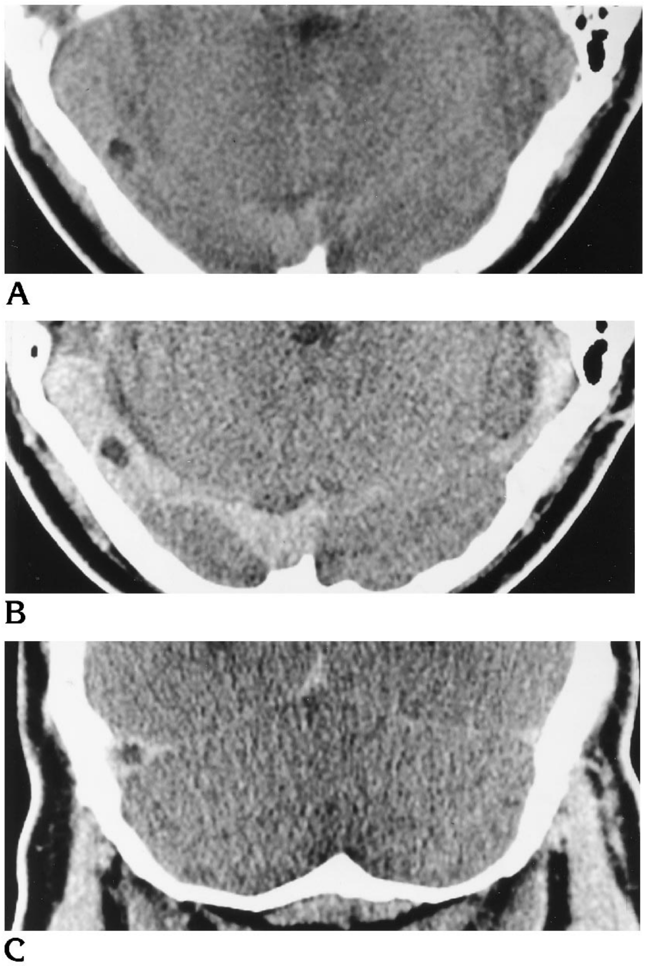

Fig 3. Noncontrast (*A*) and contrast-enhanced (*B*) axial CT scans show a granulation in the lateral third of the right transverse sinus. Postcontrast coronal scan (*C*) confirms the position of the granulation inside the sinus.

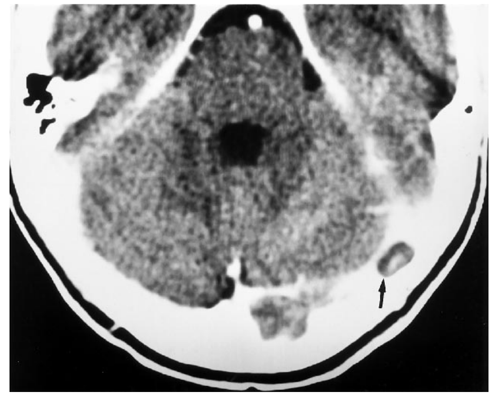

Fig 4. Postcontrast axial CT scan shows a granulation in the lateral aspect of the left transverse sinus with central calcification and a peripheral halo of CSF density (*arrow*).

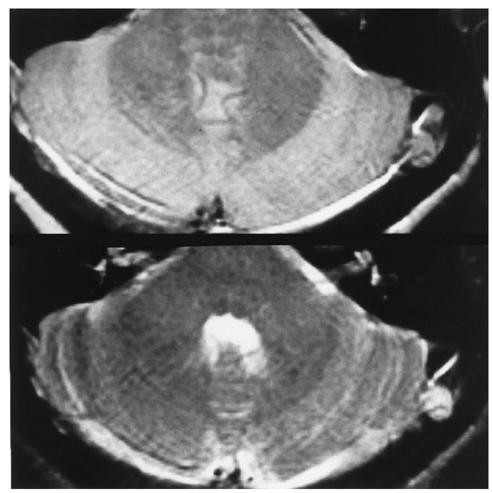

Fig 5. Proton density–weighted (*top*) and T2-weighted (*bottom*) axial MR images show a large granulation in the lateral third of the left transverse sinus with two septa.

fluid (CSF) as determined visually or by region-of-interest measurements. Three granulations were calcified and could be seen easily on both precontrast and postcontrast studies. One granulation appeared to be entirely calcified but the other two showed varying amounts of central calcification with a surrounding halo of CSF density (Fig 4).

MR studies were available in 14 patients with 18 granulations. These studies were not always targeted to the posterior cranial fossa and not all granulations were shown in every sequence. On T1-weighted images, 12 granulations were isointense with CSF and 5 were isointense with gray matter. Identification of granulations isointense with gray matter was difficult in 3 of these 5 granulations. Intermediate and T2-weighted images showed uncalcified granulations to be isointense with CSF. It was on thin-section T2-weighted images that these granulations were most readily identified by MR imaging (Figs 2 and 5). The one calcified granulation examined with MR imaging was almost isointense with white matter on T1-weighted images and was not noted prospectively. It appeared hypointense relative to CSF on intermediate and T2-weighted images, and showed a prominent hypointense interface with the flow void of the sinus.

MR angiography was available in five patients with six granulations. Five of the granulations were easily seen on projection images but one smaller granulation could only be identified on partition images. Oblique projection images made three granulations appear elongated, and they could have been mistaken for thrombus in a different clinical context (Fig 6A).

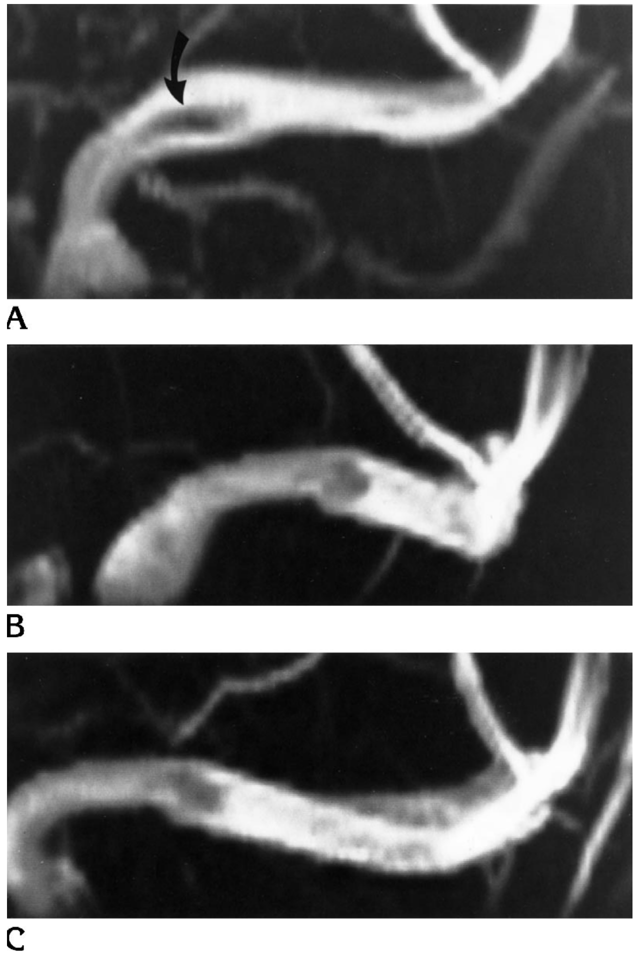

Fig 6. *A*, Phase-contrast MR angiogram shows a granulation in the lateral part of the transverse sinus. This indents the sinus and appears as a long elliptical defect on this oblique projection view (*arrow*).

B and *C*, Phase-contrast MR angiograms, two projection views of a different patient (same as in Fig 3), show the spherical filling defect of an arachnoid granulation in the transverse sinus.

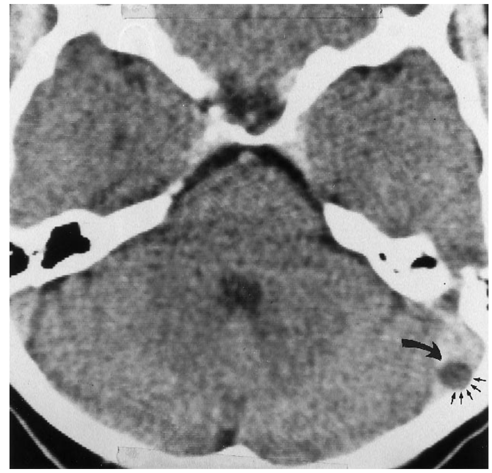

Fig 7. Postcontrast axial CT scan shows granulation in the superior aspect of the sigmoid sinus (*arrows*). The adjacent bone is indented, a finding that was confirmed on bone window images.

Venous phase digital subtraction angiography showed five granulations in four patients, which generally were best seen on frontal views, but were also seen in the lateral projection (Fig 2B). These appear as well-defined static filling defects within a sinus opacified by either carotid or vertebral injections.

The morphology of these granulations varies. Their density/intensity generally parallels that of CSF. Internal structures that are linear or septate in appearance could be seen in 18 of the 41 granulations (Fig 5). This is probably a falsely low figure, as these internal structures are best seen on high-resolution MR images. Three granulations had calcium within them. One granulation was immediately adjacent to the inner table of the calvaria and there was definite evidence of bone remodeling around the granulation (Fig 7). Two other granulations showed possible bone remodeling. In 16 granulations there was a close relationship with a vessel, or vessels, that appears to be draining into the sinus immediately adjacent to the granulation. In 4 of these 16, the vein is apparently traced directly into the granulation (Fig 2). This feature was best seen on three-dimensional T1-weighted images after injection of contrast material. Granulations did not change over time, but the longest period between studies was only 2 years.

A review of the symptoms of patients showed that 13 of the 32 had symptoms that could conceivably be related to the posterior fossa, such as pulsatile tinnitus, vertigo, ataxia, deafness, Meniere syndrome, or ear pain. The remaining 19 had symptoms unrelated to the posterior fossa or venous sinuses. Clinical follow-up, which ranged from 3 months to 5.5 years, has shown partial or complete resolution of symptoms in 18 patients, no change in 9 patients, and no relevant development of symptoms in 4 patients whose general condition has otherwise deteriorated from systemic disease. In 1 patient with end-stage renal failure and advanced lymphoma, severe truncal ataxia developed. The granulation in this patient was unchanged over 3 weeks and there were no other posterior fossa abnormalities. Symptoms were thought by the referring clinicians to be drug-related. No patient has had a diagnosis that was considered relevant to the venous sinuses, such as increased intracranial pressure, dural vascular malformation, or sinus thrombosis.

The frequency of these granulations is not accurately known. Over a 9-month period, 3100 routine CT scans were prospectively viewed and 9 granulations were discovered. Since not all of these had adjacent thin-section views of the posterior fossa after intravenous administration of contrast material (our routine is 3-mm-thick sections every 5 mm), this probably underestimates the true frequency. In 200 MR studies obtained for possible acoustic neuroma, three-dimensional imaging was performed, giving 2-mm adjacent sections through the sinuses, and 2 granulations were found. T1-weighted imaging without contrast administration is not the optimal way to discover granulations by MR imaging, so this also underestimates the frequency. The prevalence of granulations in the adult population would thus appear to be at least between 0.3 and 1 in 100.

Discussion

Arachnoid granulations in the transverse and sigmoid sinuses appear to be normal anatomic variants that surely have been seen by many radiologists. Tokiguchi et al (1) recently published a description of such a granulation, shown by CT and confirmed at autopsy, that correlates well with the appearances described in this study. Their image of a microscopic specimen of a collapsed granulation gives an indication of the internal structure of these bodies. Mamourian et al (2) described the CT and MR appearance of a lesion they concluded was a giant arachnoid granulation in the transverse sinus that matches our observations. They also described autopsy features of two giant arachnoid granulations in the transverse sinuses that they regarded as incidental findings. We believe these granulations are common, have a characteristic appearance, and are rarely a cause of symptoms. This recognition of normality averted the planned surgical excision of a granulation from one of our patients, who is symptom-free 4 years later.

Arachnoid granulations (pacchionian bodies) are mostly found clustering in parasinusoidal blood lakes alongside the superior sagittal sinus. Anatomic descriptions of them within the lateral sinus date back to 1920 (3). They are bulbous aggregates of fibroelastic tissue that are continuous with the subarachnoid space. CSF circulates through these granulations and thereby enters the venous system. Arachnoid granulations are reputed to increase in size and number with age (3–5). Upton and Weller (6) described different histologic appearances of arachnoid granulations with age; more cellular, less complex granulations occur in younger patients. Wolpow and Schaumburgh (7) described variability of size and morphology of arachnoid granulations in different sites in the same patient. Radiologically, they have been said to be calcified, to simulate destructive lesions in the calvarium (4, 8), to mimic dermoid cysts in the young (9), to be a potential cause of CSF otorrhea in the temporal bone (10), and frequently to extend into the superior sagittal sinus (5, 10–12).

Granulations in the transverse or sigmoid sinus are best found on adjacent thin-section CT scans after intravenous administration of contrast material. When not calcified, they are isodense with CSF and are usually visible on noncontrast scans of the same section thickness and position. With MR imaging, the granulations are most conspicuous on thin-section T2-weighted images or on T1-weighted images obtained after contrast administration, because they contrast with the signal of the sinus. The variable low-contrast difference between the granulation and the sinus on noncontrast T1-weighted images means they may often be missed on this sequence. Spin-echo T1-weighted studies have shown five granulations to be isointense with gray matter, possibly because of a partial volume effect but more probably because of the varying amount of stromal tissue that occurs within these spaces (6, 7). In the other 12 granulations seen on T1-weighted images, and in all the granulations seen on the proton density–weighted and T2-weighted images, the signal intensity of uncalcified granulations was the same as CSF. Previous reports of surgically proved arachnoid granulations (4, 10) at other sites have described their signal intensity on MR images as being similar or continuous with CSF. With MR angiography, these granulations are usually well seen (Fig 6). They are best assessed on the partition images, as they may be missed on some of the maximum intensity projection views. They appear as rounded or elliptical areas with no signal. The elliptical defects may simulate thrombus, but a review of T2-weighted images usually shows their true nature.

Four filling defects seen in the transverse sinuses of 14 healthy volunteers on MR angiograms were considered to be arachnoid granulations (R. Knutzon, J. Tanabe, P. Baum, and W. Dillion, “MR Venography: Artifacts, Normal Anatomic Variants, and Their Differentiation from Thrombus,” *Proceedings of the 31st Annual Meeting of the American Society of Neuroradiology, May 16–20, 1993,* 90 [abstract]). Filling defects have been previously described in the transverse sinus at angiography (13) and have been labeled as inflow artifacts from unopacified cerebellar veins. Three granulations that were shown by MR imaging in our study correlated well with defects in the venous phase of digital subtraction angiography (Fig 2).

The internal structures seen in 18 granulations (Fig 5) are not unexpected from histologic descriptions (6, 7) and probably correspond to vessels or to a reticulum of fibrous tissue that may appear as discrete septa. These are best assessed on MR images, but can occasionally be noted on CT scans. In 16 granulations there was a close relationship with a vessel or vessels, which apparently entered the granulation in 4 cases. The 3 giant arachnoid granulations found at autopsy by Mamourian and Twofighi (2) were all shown to contain a relatively large blood vessel in the center. Two of these lesions were in the transverse sinus. Central enhancement in a transverse sinus giant arachnoid granulation in one of their cases also suggested the presence of a central vascular channel. Browder et al (14) found that all but 2 of 23 nodules in the transverse sinus were located at the site where the vein of Labbé joins the sinus. Upton and Weller (6) described a small number of endothelial-lined channels on the surface of arachnoid granulations not seen in arachnoid villi. Grossman and Potts (5), in an angiographic and pathologic study, noted 49% of patients over the age of 40 had veins closely related to arachnoid granulations, and they considered this relationship to be casual. The significance of vessels associated with arachnoid granulations remains unclear. Bone remodeling of the inner calvarium was present in one of our cases (Fig 7) and suggested in two others. Bone erosion from granulations at other sites has been well described (4, 8–10), and such a pressure effect when they lie in a venous sinus is not surprising.

Forty percent of the patients in our series had symptoms that could conceivably be related to disease in the dural sinuses of the posterior fossa. However, the failure of any firm pathologic diagnosis to be made subsequent to all radiologic studies, and the absence of any related deleterious outcome to the patients, are pertinent. No patient had any significant, unexpected illness during the follow-up periods, which ranged from 3 months to more than 5 years. Moreover, the symptomatology of many of these patients prompted investigation with thin, closely spaced CT or MR sections, which increased the likelihood of discovering granulations.

The frequency with which these granulations were found indicates that they are so common that a firm association with such symptomatology must be guarded. However, it is possible that a large, unilateral granulation in a dominant sinus could cause partial obstruction of venous flow. Tress et al (personal communication, 1994) have indicated the possibility of partial obstruction of the sinus related to granulations in patients with idiopathic, raised intracranial pressure. Pressure gradients were recorded on either side of these granulations, but pressure gradients were also observed between the middle and distal transverse sinuses in patients with idiopathic intracranial hypertension without granulations or any other abnormality. None of our patients had symptoms that warranted invasive investigations, such as pressure measurements.

The rate of occurrence we report of between 0.3 and 1 in 100 adults appears to be conservative. Four filling defects were noted in the transverse sinuses on MR angiograms of 3 of 14 healthy volunteers by Knutzon et al (presented at ASNR meeting, 1993). Browder et al (14) found 23 polypoid tumors in the transverse sinuses of 295 autopsy cases. Our experience suggests that in the vast majority of cases the discovery of a granulation in a sinus is entirely innocuous. The differential diagnosis of a small arachnoid cyst could be considered in cases in which the defects only indent the sinus but where their site, size, and overall appearance suggest they are all the same anatomic variation.

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