



Dural Sinus Thrombosis: Sources of Error in Image Interpretation

James M. Provenzale^{1,2}
Peter G. Kranz¹

OBJECTIVE. The purpose of this article is to bring some of the potential causes of false-positive and false-negative interpretations of dural sinus thrombosis (DST) on cross-section imaging studies to the attention of radiologists.

CONCLUSION. The prompt diagnosis of DST can be important in many cases and a false-positive diagnosis can cause a delay in establishing the correct diagnosis as well as lead to implementation of inappropriate therapy. We hope that this article helps to reduce the number of such cases in the daily practice of the reader.

Dural sinus thrombosis (DST) is a disease entity in which early diagnosis can make an important difference with regards to patient outcome. Inability to correctly diagnose DST can occasionally allow the disease to progress to a critical state manifested by cerebral infarction, impaired consciousness, coma, and death. In one recent study, a substantial average delay of 7 days between the onset of symptoms and imaging-based diagnosis was found [1]. In another study, 7% of patients with DST died in the acute stage of the disease [2]. The goal of this review is to inform the reader of potential causes of misdiagnosis of DST in the hopes of facilitating early diagnosis.

In many cases, false-negative interpretations of DST imaging studies are not due to misinterpretation of findings that clearly indicate abnormal flow. Instead, misinterpretations are often due to lack of appropriate specific attention to the appearance of the dural sinuses. Some reasons for this difficulty are, first, that the dural sinuses are frequently located on the edges of an image rather than in the central portion and, second, that images of the superior sagittal sinus are at the end of the series of images being reviewed. Thus, unless a specific effort is made to include the dural sinuses in the search pattern used to evaluate images, an abnormality within the dural sinuses can be relatively easily missed.

An indication to the radiologist that DST is being considered by the clinician ordering the study would help alleviate the difficulties outlined. However, in many cases, the ordering

physician has either not considered DST as a diagnosis or has not communicated the clinical suspicion of DST to the radiologist. In one recent article, the authors reported that DST was listed as the clinical diagnosis on the study requisition in only 5% of CT cases that showed DST and in 33% of MR cases (in which the diagnosis was not already known) [3].

Misdiagnosis of DST is also often due to difficulties in correctly interpreting confusing (or contrary) imaging findings related to the dural sinuses. The remainder of this review is intended to outline difficulties in the interpretation of imaging findings related to DST on various forms of imaging.

Review of Imaging Findings Considered Diagnostic for DST

A number of findings in DST have been described on CT including the so-called cord sign (which represents a hyperdense thrombosed vein), the dense dural sinus sign (also referred to as the hyperdense dural sinus sign), and the empty delta sign on contrast-enhanced CT (Fig. 1). The cord sign has been reported to be insensitive, being present in only 5% of cases [4]. The dense dural sinus sign is also reported in only 20% of cases and, therefore, is an insensitive sign [4]. However, the empty delta sign appears to be more sensitive because it has been reported in 70% of cases [5]. Unenhanced CT scans are more commonly used as the first imaging study in patients with new clinical symptoms. Hence, the empty delta sign, seen on contrast-enhanced studies, will often not be available. In one re-

Keywords: dural sinus thrombosis, CT angiography, infarction, MR angiography

DOI:10.2214/AJR.10.5323

Received July 11, 2010; accepted without revision July 15, 2010.

¹Department of Radiology, Duke University Medical Center, Box 3808, Durham, NC 27710. Address correspondence to J. M. Provenzale.

²Department of Radiology, Oncology, and Biomedical Engineering, Emory University School of Medicine, Atlanta, GA.

AJR2011; 196:23–31

0361–803X/11/1961–23

© American Roentgen Ray Society

cent study, unenhanced CT was reported to have a sensitivity of 73% for the detection of DST [6]. However, in that study readers were specifically asked to examine unenhanced CT scans of patients with confirmed DST, which is a situation very different from a clinical environment in which the diagnosis is rarely previously known and, often, unanticipated.

Similar findings to those on CT are present on MRI. Thus, the absence of flow void within a thrombosed dural sinus is the equivalent of a hyperdense sinus on CT. Although the exact sensitivity of absence of a flow void for detection of DST is hard to determine, it is likely very high. An empty delta sign, similar to that on contrast-enhanced CT, can also be seen on MRI. Nonetheless, in some cases, the determination of DST using spin-echo techniques (i.e., without MR venography) can be difficult. Nonetheless, a number of diagnostic clues can be garnered from the spin-echo images in equivocal cases. For instance, localizer images obtained using gradient-echo technique often show flow-related enhancement in dural sinuses (Fig. 2). On occasion, the authors have used such images to make a determination about the patency of the dural sinuses and have avoided the need for repeat MRI for performing MR angiography. Similarly, pulsation artifact in the phase-encoding direction on unenhanced MR images can also be used to determine the likelihood of dural sinus patency in equivocal cases (Fig. 3).

On that basis, it is important that the radiologist understand the relatively high rate at which obvious findings indicating DST are absent. On unenhanced CT, one of the major findings of DST is that of a hyperdense sinus. In the medical literature, this sign has been variably referred to as the "dense vein" sign [4], the "cord sign" [7], and the "triangle" sign [3]. The fact that a hyperdense sinus has been reported in only 20% of patients in some series [4] indicates that one of the signs that most radiologists have learned as highly suspicious for DST is present in only a small minority of patients. In another study, a "hyperdense dural" sign was present in 58%, again indicating that the absence of this sign is not reliable for excluding the diagnosis of DST. Finally, one report addressed the influence of clinical suspicion of DST in success in diagnosing findings on unenhanced CT [3]. That report indicated that when the diagnosis was not suspected on clinical grounds, the false-negative rate on CT was 53%. Thus, it is important that radiologists learn the clues that can be found on the requisition or

in the electronic medical record that should raise suspicion of DST. These clues include a previous thrombotic event (e.g., deep venous thrombosis), pulmonary embolism, or recurrent spontaneous abortions, which raise the possibility of a hypercoagulable state [8].

Causes of False-Negative Cases Using CT and MR Techniques

False-Negative Cases on Unenhanced CT

A false-negative finding for DST on unenhanced CT may be caused by a lack of increased density of a thrombosed dural sinus (e.g., over time, transition of a previously hyperdense dural sinus to one that is isodense with brain) [7, 9] (Fig. 4). Another cause is volume averaging of a dural sinus with normal tissue, which is most commonly encountered in the transverse sinus on axial CT images. Finally, a small dural sinus, even when hyperdense, can be difficult to visualize against the high-density background of adjacent skull.

False-Negative Cases on Contrast-Enhanced CT

Few false-negative cases of DST on contrast-enhanced CT exist. However, some observers have noted that on occasion a so-called empty delta sign is not seen even though DST is depicted on catheter angiography [10]. Investigators have attributed this finding to either the high density of thrombus that is not visible against the background of contrast enhancement of the walls of the dural sinus (in cases in which the thrombus is in the acute stage) or because (in the case of a chronic thrombus) the thrombus is partially recanalized.

False-Negative Cases on CT Angiography

False-negative causes of DST on CT venography are uncommon. One technical cause of a false-negative study is inappropriate timing of scanning after administration of contrast material. If scanning is performed too soon after contrast material administration, the dural sinuses are poorly opacified, which can decrease the contrast resolution between the thrombus and opacified blood [11].

False-Negative Cases on MRI

In large part, false-negative cases on MRI result from simulation of normal signal intensity by thrombosed dural sinuses. Part of the difficulty in establishing the diagnosis of DST on MRI is that, in some circumstances, the signal intensity of the thrombosed sinus can simulate normal brain tissue or normal blood flow. On T1-weighted images, acute thrombus may be isointense to

brain and thus less conspicuous compared with subacute thrombus, which is hyperintense on T1-weighted images. One series observed isointense signal of thrombus relative to brain tissue in approximately 50% of cases on T1-weighted imaging [3] (Fig. 5).

Another confounding factor is the presence of hypointense thrombus on T2-weighted images simulating a flow void; in one study, this finding was found in approximately 10% of the cases of DST [12]. Another series reported a hyperintense signal abnormality within a thrombosed dural sinus on T2-weighted images in only 27% of cases on initial MR examination [13].

When gadolinium-containing contrast agents are administered, thrombus is expected to result in a filling defect within the enhancing venous sinus (i.e., the so-called empty delta sign), as is seen with contrast-enhanced CT. This appearance can, thus, be distinguished from that of the homogeneous contrast enhancement of a patent dural sinus, which is often accompanied by pulsation artifacts in the phase-encoding direction. However, on occasion, contrast-enhanced T1-weighted images of DST in chronic stages can also show homogeneous contrast enhancement of the thrombosed dural sinus (often with accompanying pulsation artifact), because of the presence of capillary channels in the thrombus, making it difficult to distinguish from a patent dural sinus [14]. Another caveat is that enhancement of the dura adjacent to a thrombosed sinus can densely contrast enhance because of the development of collateral vessels; as such, the dural enhancement can be mistaken as an indication of other disease entities, such as neurosarcoidosis [15].

Causes of False-Positive Cases Using CT and MR Techniques

False-Positive Cases on Unenhanced CT

On unenhanced CT, the most common cause of a false-positive case is a high hematocrit (e.g., in patients with polycythemia vera) causing a hyperdense sinus [16] (Fig. 6). However, the arteries of such patients also frequently have a hyperdense appearance, which is a clue to the correct diagnosis. The problem of a normal hyperdense appearance of the dural sinuses is also frequently encountered in infants and young children, in whom the relative density of the dural sinus compared with brain tissue is typically high for two reasons: first, a usually higher hematocrit value than in adults and, second, a typically lower brain density than in adults.

False-Positive Cases on Contrast-Enhanced CT

Among the causes of false-positive cases for DST on contrast-enhanced CT are normal variant structures located within a dural sinus, such as fenestrations and arachnoid granulations. Arachnoid granulations have density that is isodense with CSF and are usually round. When seen on images showing the short axis of a dural sinus, arachnoid granulations can be mistaken for thrombus when they fill most of the lumen diameter. However, they can usually be distinguished from thrombus on images showing the long axis of the dural sinus by their rounded shape and short extent along the dural sinus. On occasion, these structures can be elongated and can extend along the length of the dural sinus, simulating thrombus [17]. The fact that arachnoid granulations are isointense with CSF (unlike thrombus) is a helpful distinguishing feature on MRI. Nonetheless, because thrombus is occasionally hypodense on unenhanced CT, confusion with arachnoid granulations that are hypodense compared with blood can occur.

False-Positive Cases on MRI

False-positive cases are seen on spin-echo MR sequences when the signal intensity of a dural sinus simulates that of thrombus. The primary causes are slow flow, in-plane flow, and entry-slice phenomena causing loss of the expected flow void within a dural sinus [11]. This difficulty is reported to be especially common in children less than 2 years old [18].

False-Positive Cases on MR Venography

Some of the causes of a false-positive finding on MR venography due to artifact are the same as those encountered on spin-echo MRI, such as saturation effects due to slow flow or in-plane flow.

Anatomic causes of false-positive findings for DST on MR venography can result from variations in the size of the dural sinuses and anatomic structures that produce filling defects. An asymmetric appearance due to hypoplasia or aplasia of one of the transverse sinuses is observed in up to 25% of healthy patients on time-of-flight (TOF) venography [19, 20], reflecting that seen at catheter angiography [21]. Nevertheless, in some cases, the discrepant size of the transverse sinuses could be misinterpreted as thrombosis, particularly in light of the fact that MRI may underrepresent the size of a vessel lumen and may cause a small venous sinus or a sinus with slow flow to appear absent. This prob-

lem may be exacerbated when a small sinus is viewed on maximum-intensity-projection (MIP) images, particularly in infants, reinforcing the need to evaluate source images when a sinus is not initially visualized on MIP images [18] (Fig. 7).

Another artifact that is frequently seen is that of a flow gap, which is seen as a segment of absent flow on MR venography even though flow is truly present on MR venography source images and spin-echo MR images [18, 19] (Fig. 7). This artifact is reported to be present in the transverse sinus in approximately 30% of normal MR scans [19]. Notably, the artifact is rarely seen in the dominant transverse sinus or other dural sinuses.

A hypoplastic transverse or sigmoid sinus is often associated with alternative venous outflow pathways such as a persistent occipital sinus and mastoid emissary veins [22] (Fig. 8). An occipital sinus has been reported to be present in 10% of normal brains on MR venography [19] (Fig. 8). Correlation with osseous anatomy on available CT images may be helpful in cases of asymmetric venous sinus caliber because congenitally small transverse or sigmoid sinuses would be expected to exhibit small jugular foramina or sigmoid sinus grooves (Fig. 9), whereas with thrombosed sinuses, the size of the sinus may be discrepant with the osseous anatomy.

Two other anatomic causes of false-positive interpretations for DST are septations and arachnoid granulations. Fibrotic bands, or septations, appear as linear filling defects in the sinuses and may be visualized more frequently on contrast-enhanced MR venography than on TOF MR venography [17]. Arachnoid granulations can simulate thrombus because they appear as filling defects on MRI (as on CT angiography) (Fig. 10). Such entities are common; in one study using high-resolution contrast-enhanced MRI of individuals with normal studies, an average of approximately five filling defects per patient were seen [9].

Artifacts related to flow and those specific to various MR venography techniques can also cause signal loss that mimics thrombus. In TOF venography, flow parallel to the plane of acquisition (in-plane flow) can produce signal loss due to saturation of signal from in-flowing protons, which can result in artifactual intravascular signal voids. Because acquisitions in TOF venography are most commonly performed in the coronal plane, signal loss due to in-plane flow becomes most apparent in vertically oriented structures such as the

distal sigmoid sinus and the internal jugular veins [23] (Fig. 11).

False-positive findings mimicking absent flow in the anterior and middle portions of the superior sagittal sinus can be produced by an inferior saturation band used to saturate arterial signal on TOF MR venography obtained using source images in the axial plane (Fig. 12). This finding is caused by the fact that blood flow in the anterior portion of the superior sagittal sinus proceeds in a cephalad direction—that is, in the same direction as arterial blood flow. Thus, the inferior saturation pulse used in TOF MR venography saturates flow not solely in the arteries but also within the anterior portion of the superior sagittal sinus. This loss of flow-related enhancement can extend far into the middle portion of the sinus. This phenomenon is not seen on MR venography performed using phase contrast imaging technique; it can be avoided by imaging in the coronal plane, not applying an inferior saturation pulse, or using phase contrast imaging.

False-Negative Cases on MR Venography

The native signal of tissue that is hyperintense on unenhanced T1-weighted images can also contribute to bright signal intensity on TOF MR venography (Fig. 13). Because thrombus can be hyperintense on unenhanced T1-weighted images, the signal produced by hyperintense thrombus can simulate flow within the dural sinus on TOF MR angiography and cause a false-negative finding (Fig. 14).

Summary

This review has brought some of the potential causes of false-positive and false-negative interpretations of DST on cross-section imaging studies to the attention of radiologists. The review was not meant to be all-inclusive and, no doubt, the reader may be able to identify some causes that are not discussed here. The prompt diagnosis of DST can be important in many cases; we hope that the discussion herein will prove valuable for assisting in film interpretation in such instances. Similarly, a false-positive diagnosis can cause delay in establishing the correct diagnosis as well as lead to implementation of inappropriate therapy. We hope that this review helps to reduce the number of such cases in the daily practice of the reader.

References

1. Ferro JM, Canhao P, Stam J, et al. Delay in the diagnosis of cerebral vein and dural sinus thrombosis: influence on outcome. *Stroke* 2009;

Provenzale and Kranz

- 40:3133–3138
2. Ferro JM, Lopes MG, Rosas MJ, Ferro MA, Fontes J. Long-term prognosis of cerebral vein and dural sinus thrombosis: results of the VENOPORT study. *Cerebrovasc Dis* 2002; 13:272–278
 3. Tang PH, Chai J, Chan YH, Chng SM, Lim CC. Superior sagittal sinus thrombosis: subtle signs on neuroimaging. *Ann Acad Med Singapore* 2008; 37:397–401
 4. Virapongse C, Cazenave C, Quisling R, Sarwar M, Hunter S. The empty delta sign: frequency and significance in 76 cases of dural sinus thrombosis. *Radiology* 1987; 162:779–785
 5. Thron A, Wessel K, Linden D, Schroth G, Dichgans J. Superior sagittal sinus thrombosis: neuro-radiological evaluation and clinical findings. *J Neurol* 1986; 233:283–288
 6. Roland T, Jacobs J, Rappaport A, Vanheste R, Wilms G, Demaerel P. Unenhanced brain CT is useful to decide on further imaging in suspected venous sinus thrombosis. *Clin Radiol* 2010; 65:34–39
 7. Linn J, Pfefferkorn T, Ivanicova K, et al. Noncontrast CT in deep cerebral venous thrombosis and sinus thrombosis: comparison of its diagnostic value for both entities. *AJNR* 2009; 30:728–735
 8. Provenzale JM, Barboriak DP, Ortel TL. Dural sinus thrombosis associated with activated protein C resistance: MR imaging findings and proband identification. *AJR* 1998; 170:499–502
 9. Vijay RK. The cord sign. *Radiology* 2006; 240:299–300
 10. Shinohara Y, Yoshitoshi M, Yoshii F. Appearance and disappearance of empty delta sign in superior sagittal sinus thrombosis. *Stroke* 1986; 17:1282–1284
 11. Rodallec MH, Krainik A, Feydy A, et al. Cerebral venous thrombosis and multidetector CT angiography: tips and tricks. *RadioGraphics* 2006; 26[suppl 1]:S5–S18; discussion, S42–S43
 12. Hinman JM, Provenzale JM. Hypointense thrombus on T2-weighted MR imaging: a potential pitfall in the diagnosis of dural sinus thrombosis. *Eur J Radiol* 2002; 41:147–152
 13. Idbah A, Boukobza M, Crassard I, Porcher R, Bousser MG, Chabriat H. MRI of clot in cerebral venous thrombosis: high diagnostic value of susceptibility-weighted images. *Stroke* 2006; 37:991–995
 14. Dormont D, Sag K, Biondi A, Wechsler B, Marsault C. Gadolinium-enhanced MR of chronic dural sinus thrombosis. *AJNR* 1995; 16:1347–1352
 15. Provenzale JM, Joseph GJ, Barboriak DP. Dural sinus thrombosis: findings on CT and MR imaging and diagnostic pitfalls. *AJR* 1998; 170:777–783
 16. Healy JF, Nichols C. Polycythemia mimicking venous sinus thrombosis. *AJNR* 2002; 23:1402–1403
 17. Liang L, Korogi Y, Sugahara T, et al. Normal structures in the intracranial dural sinuses: delineation with 3D contrast-enhanced magnetization prepared rapid acquisition gradient-echo imaging sequence. *AJNR* 2002; 23:1739–1746
 18. Rollins N, Ison C, Booth T, Chia J. MR venography in the pediatric patient. *AJNR* 2005; 26:50–55
 19. Ayanzen RH, Bird CR, Keller PJ, McCully FJ, Theobald MR, Heiserman JE. Cerebral MR venography: normal anatomy and potential diagnostic pitfalls. *AJNR* 2000; 21:74–78
 20. Alper F, Kantarci M, Dane S, Gumustekin K, Onbas O, Durur I. Importance of anatomical asymmetries of transverse sinuses: an MR venographic study. *Cerebrovasc Dis* 2004; 18:236–239
 21. Newton TH, Potts DG. *Angiography*. St. Louis, MO: Mosby, 1974:v, xiii, 4, 875–2786
 22. Kobayashi K, Suzuki M, Ueda F, Matsui O. Anatomical study of the occipital sinus using contrast-enhanced magnetic resonance venography. *Neuroradiology* 2006; 48:373–379
 23. Lewin JS, Masaryk TJ, Smith AS, Ruggieri PM, Ross JS. Time-of-flight intracranial MR venography: evaluation of the sequential oblique section technique. *AJNR* 1994; 15:1657–1664

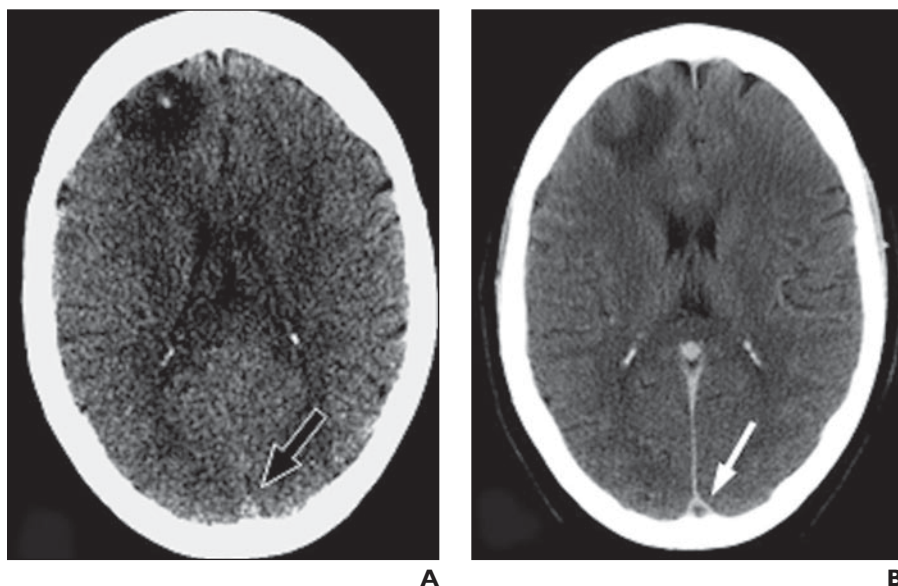


Fig. 1—Findings of dural sinus thrombosis on CT in 27-year-old woman with history of ulcerative colitis, severe headache, and obtundation. This case represents initial manifestation of hypercoagulable state due to ulcerative colitis.

A, Unenhanced axial CT image shows hyperdense appearance of superior sagittal sinus (arrow), consistent with thrombosis. Note hypodense region in right frontal lobe consistent with venous infarction that contains a small rounded hyperdense region consistent with a thrombosed vein

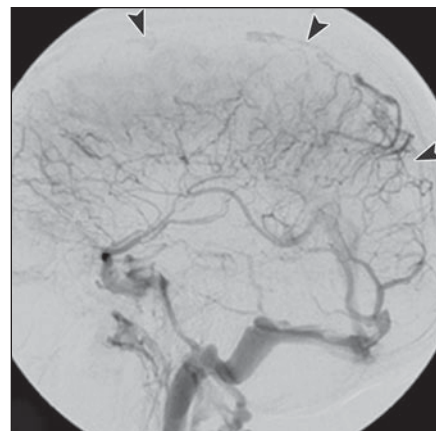
B, Contrast-enhanced axial CT image shows lack of enhancement of superior sagittal sinus (arrow), consistent with thrombosis. This finding is referred to as “empty delta sign.”

Errors in Imaging-Based Diagnosis of DST

Fig. 2—Use of localizer images to indicate loss of flow-related enhancement as indicator of dural sinus thrombosis in 41-year-old woman with headache and aphasia.

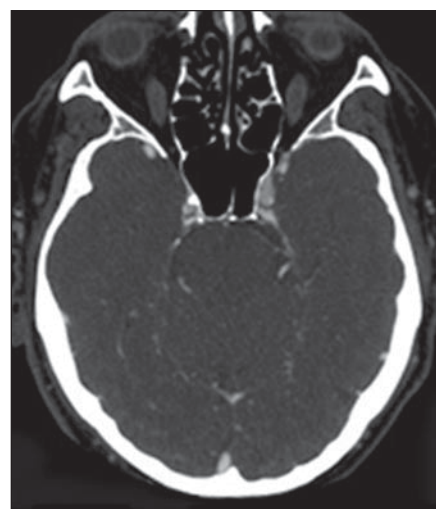
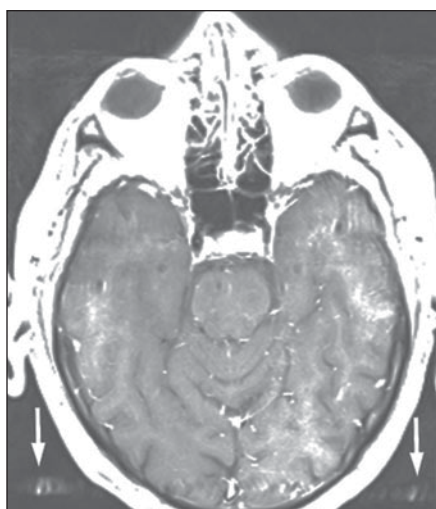
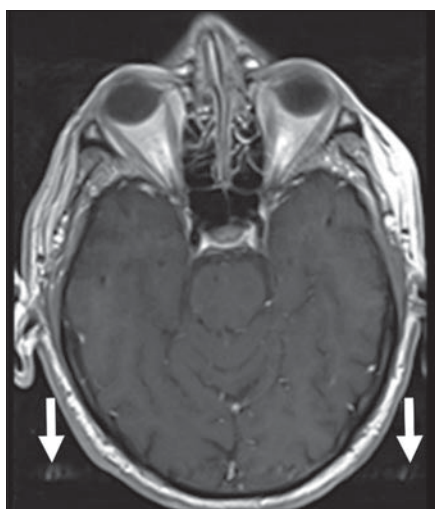
A, Gradient localizer image from MR examination. Patent venous sinuses show flow-related enhancement (*black arrow*). Thrombosed superior sagittal sinus (*white arrow*) lacks expected flow-related enhancement.

B, Lateral view from catheter-based cerebral angiogram in venous phase confirms thrombosis of superior sagittal sinus (*arrowheads*).



A

B



A

B

C

Fig. 3—Use of artifact in phase-encoding direction as sign supporting presence of flow in superior sagittal sinus in 79-year-old man.

A, Contrast-enhanced axial T1-weighted image shows subtle findings of pulsation artifact in air (*arrows*) generated by flow in dural sinus, indicative of patency.

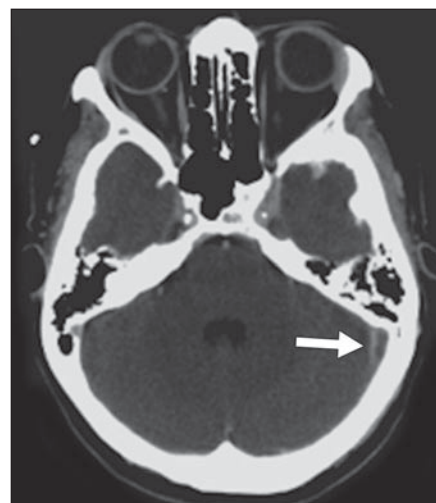
B, Same image as shown in **A** but with wider window settings to make artifact (*arrows*) more conspicuous.

C, Axial source image from CT venogram confirms patency of dural sinus.

Fig. 4—False-negative unenhanced CT in 56-year-old woman with severe headache, chronic cough, and 15-lb (7-kg) weight loss. Chest CT showed large pulmonary mass and hepatic metastases. This case represents dural sinus thrombosis (DST) as initial manifestation of hypercoagulable state due to carcinoma.

A, Unenhanced axial CT image shows normal density of left sigmoid sinus (*arrow*).

B, Contrast-enhanced axial image depicts filling defect (*arrow*) in left transverse sinus, consistent with thrombosis. Subsequent MR angiography (not shown) confirmed DST.



A

B

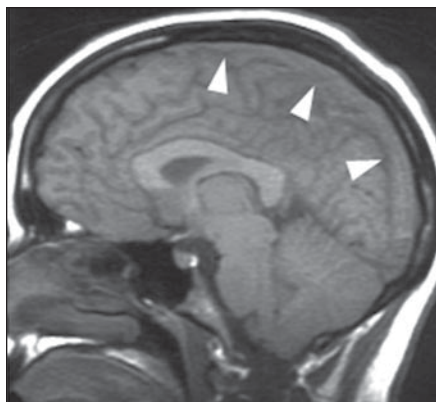
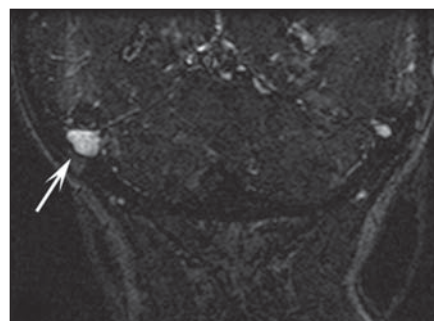
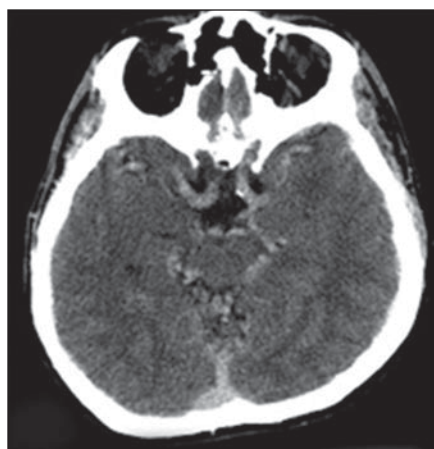
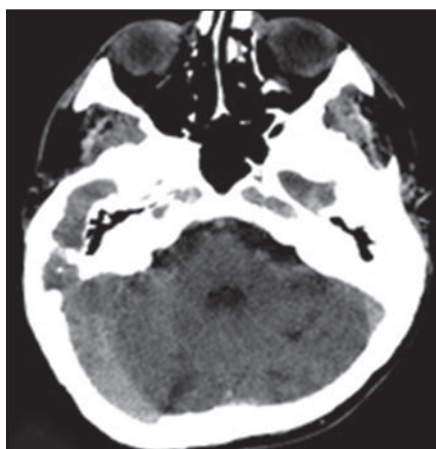


Fig. 5—Unenhanced CT image in 40-year-old woman with headaches and photophobia shows replacement of the expected flow void in the superior sagittal sinus by signal that is relatively isointense with gray matter (*arrowheads*). In this circumstance, signal intensity of thrombosed dural sinus is not particularly conspicuous against background of normal brain tissue and can result in false-negative interpretation of study.



A

B

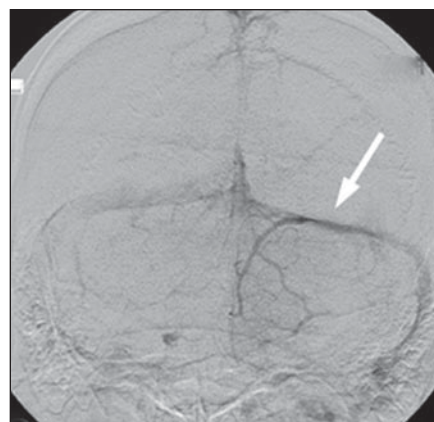
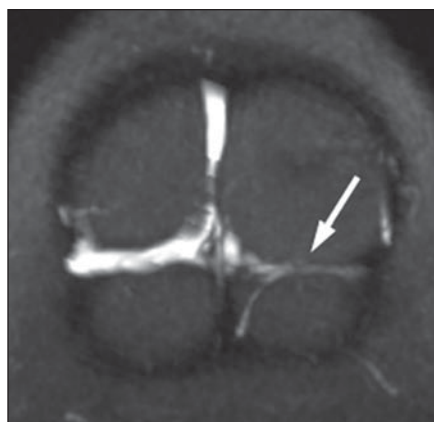
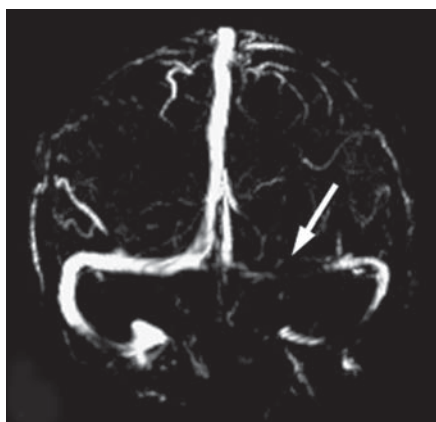
C

Fig. 6—False-positive unenhanced CT in 18-year-old man with polycythemia vera and headaches.

A, Unenhanced axial CT image shows hyperdense appearance of transverse sinuses, which could potentially represent dural sinus thrombosis.

B, Unenhanced axial CT image at more cephalad level than **A** shows straight sinus is also hyperdense. However, arteries are also dense, which indicates that dural sinuses may be hyperdense because of polycythemia.

C, Representative coronal contrast-enhanced image from MR angiogram shows patency of junction of transverse and sigmoid sinuses (*arrow*).



A

B

C

Fig. 7—Example of artifactual flow gap simulating dural sinus thrombosis on maximum-intensity-projection (MIP) image.

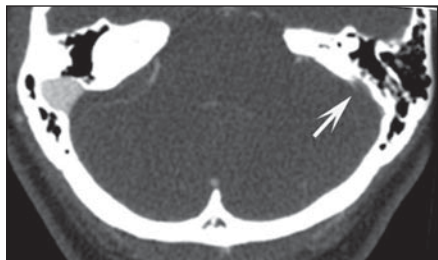
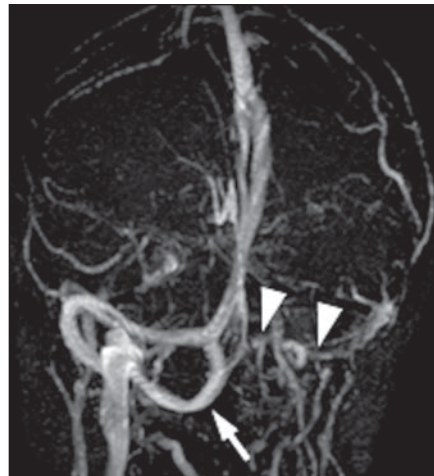
A, Coronal MIP image generated from unenhanced 2D time-of-flight MR angiography (MRA) shows apparent region of absent flow (*arrow*) in left transverse sinus.

B, Coronal source image from unenhanced MRA shows that left transverse sinus, although smaller than right transverse sinus, has flow-related enhancement (*arrow*) and, thus, is patent.

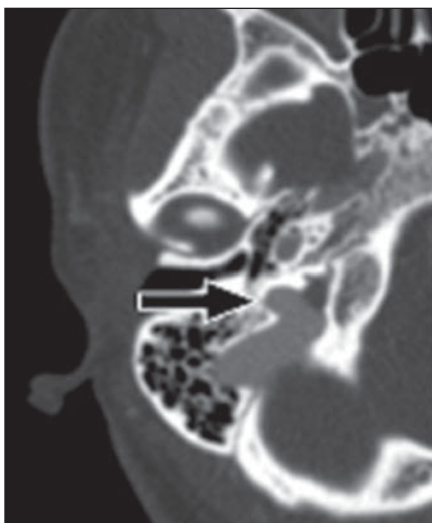
C, Catheter angiogram during venous phase, anteroposterior view, confirms patency of left transverse sinus (*arrow*).

Errors in Imaging-Based Diagnosis of DST

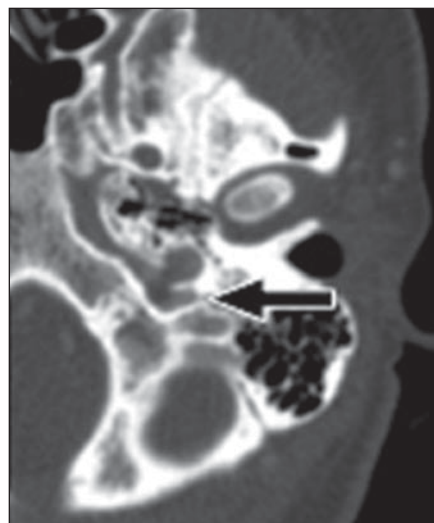
Fig. 8—Use of identification of collateral venous pathway to confirm that apparently stenotic dural sinus is, in fact, congenital in nature in 60-year-old man. Reconstructed image from unenhanced time-of-flight MR venogram shows that left transverse sinus (*arrowheads*) is markedly narrowed, which could be mistaken for stenosis due to thrombosis. However, occipital sinus (*arrow*) is present on patient's right; presence of this anatomic variant suggests that narrowing of contralateral transverse sinus is congenital.



A



B



C

Fig. 9—Example of use of bone window settings to confirm that narrowing of transverse sinus is due to congenital hypoplasia in 30-year-old woman with headache. **A**, Source image from CT venogram shows that left sigmoid sinus (*arrow*) is barely visible. Note, however, proportionately small sigmoid sinus osseous grooves. **B**, Image at level of right jugular foramen (*arrow*) shows that sigmoid sinus groove has normal size. **C**, Image at level of left jugular foramen (*arrow*) shows that sigmoid sinus groove is markedly diminished in size, which serves as further evidence that left sigmoid sinus is congenitally narrowed.

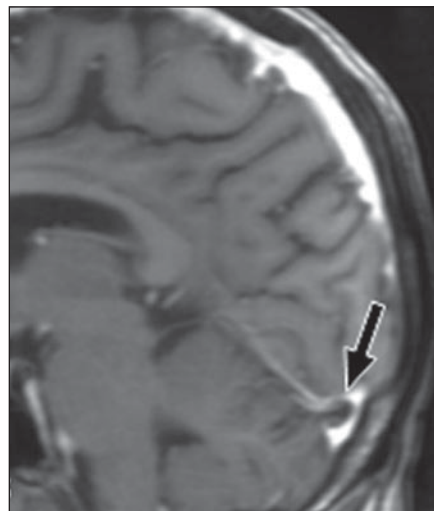
Fig. 10—Depiction of arachnoid granulations as cause of filling defects within dural sinus of 66-year-old man.

A, Coronal contrast-enhanced T1-weighted image shows filling defect in left transverse sinus (*arrow*). Defect can be confidently identified as arachnoid granulation based on its round shape, smooth margins, and small punctate foci of internal enhancement.

B, Sagittal contrast-enhanced T1-weighted image shows that filling defect (*arrow*) communicates with subarachnoid space, further indication that defect is caused by arachnoid granulation.



A



B

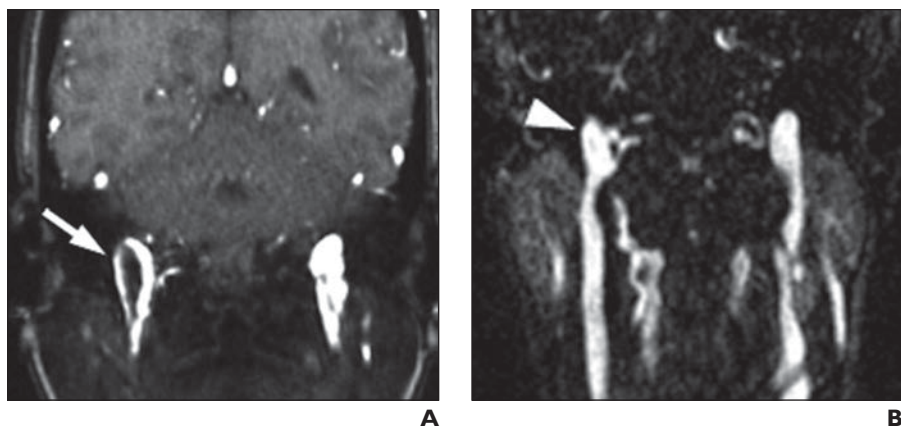


Fig. 11—In-plane flow as potential source of false-positive MR venogram in 17-year-old girl being evaluated for papilledema.
A, Coronal source image from unenhanced time-of-flight MR venogram does not show signal in central portion of right jugular vein (*arrow*), which could be misinterpreted as thrombosis.
B, Coronal source image obtained during venous phase of contrast-enhanced MR angiogram shows that vein (*arrowhead*) is, in fact, patent. Absence of signal in **A** was likely due to in-plane flow saturating signal from flowing blood.

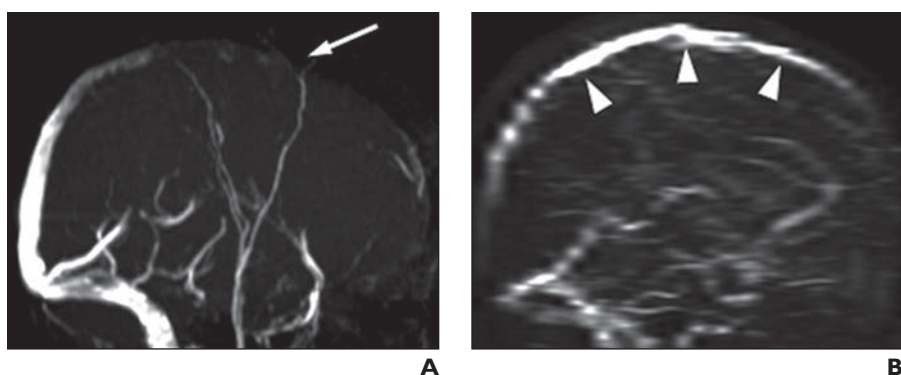


Fig. 12—Inferior saturation band during unenhanced 2D time-of-flight (TOF) MR venography as potential cause of false-positive study in 29-year-old woman. Imaging was performed in axial plane and inferior saturation band was used to diminish signal intensity from arterial flow. (Reprinted from [15])
A, Reconstructed image from MR venogram shows absence of signal in anterior and middle portions of superior sagittal sinus (*arrow*). Finding is due to saturation of venous flow in cephalad direction by inferior saturation band.
B, Phase contrast venography performed during same MR examination confirms patency of sinus (*arrowheads*). Alternative means to assess patency of dural sinus would have been to repeat TOF venography in axial plane after removal of inferior saturation band.

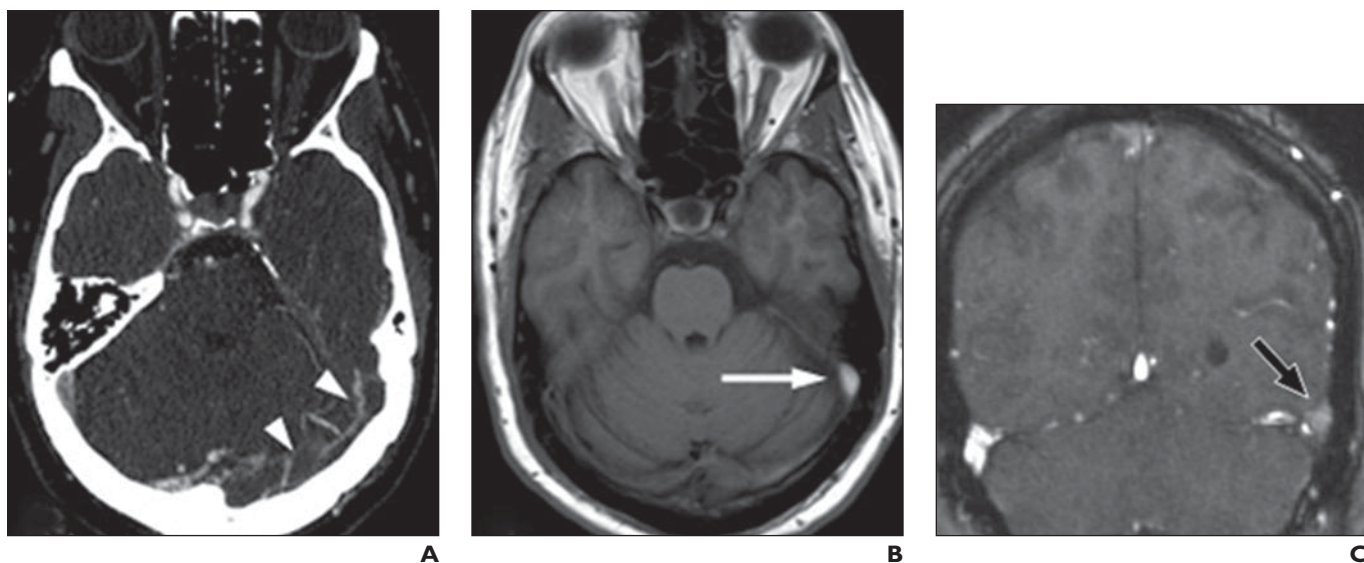


Fig. 13—Transmission of bright signal on unenhanced T1-weighted images onto MR angiography and contrast-enhanced T1-weighted images, so-called shine-through effect, as potential cause of false-negative interpretation in 50-year-old woman with impaired consciousness.
A, Axial source image from CT venogram shows lack of contrast enhancement of left transverse sinus (*arrowheads*), consistent with thrombosis.
B, Unenhanced axial T1-weighted image shows hyperintense left sigmoid sinus (*arrow*).
C, Source image from unenhanced time-of-flight MR venogram shows thrombosed transverse sinus (*arrow*) has bright signal due to transmission of bright appearance on T1-weighted images onto MR venogram. Although signal intensity in left transverse sinus is not as bright as signal intensity in other (patent) dural sinuses, bright signal could be mistaken for flow.

(Fig. 13 continues on next page)

Errors in Imaging-Based Diagnosis of DST

Fig. 13 (continued)—Transmission of bright signal on unenhanced T1-weighted images onto MR angiography and contrast-enhanced T1-weighted images, so-called shine-through effect, as potential cause of false-negative interpretation in 50-year-old woman with impaired consciousness.
D, Contrast-enhanced coronal T1-weighted image shows bright appearance of thrombosed sinus (*arrow*) instead of expected empty delta sign.

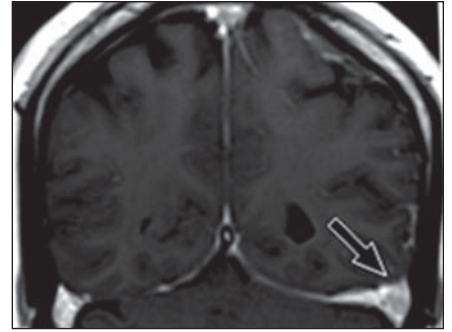
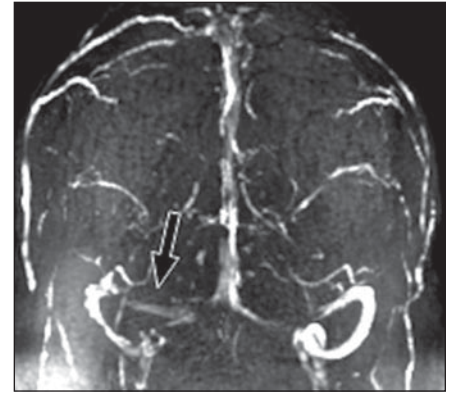
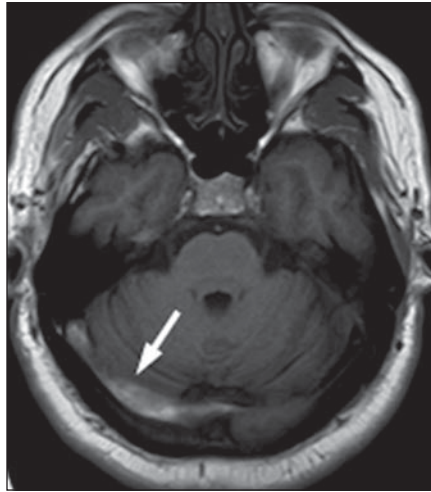


Fig. 14—Example of transmission of bright signal on unenhanced T1-weighted image onto MR venogram in 55-year-old man being evaluated for headache, nausea, and photophobia.

A, Axial unenhanced T1-weighted image shows high signal in right transverse sinus (*arrow*) due to thrombus.

B, Coronal maximum-intensity-projection image from unenhanced MR venogram shows transmission of bright signal from unenhanced T1-weighted image, so-called T1 shine-through effect, in right transverse sinus (*arrow*), which simulates flow in patent dural sinus.



A

B