0733–8619/92 $0.00 + .20

CEREBRAL VENOUS THROMBOSIS

Alain Ameri, MD, and Marie-Germaine Bousser, MD

Cerebral venous thrombosis (CVT) has been recognized since the early part of the nineteenth century, when Ribes[76] described the clinical history of a 45-year-old man who died after a 6-month history of severe headache, epilepsy, and delirium. Postmortem examination showed widespread malignancy with thrombosis of the superior sagittal sinus (SSS), left lateral sinus (LS), and a cortical vein in the parietal region. This was probably the first detailed description of cerebral venous thrombosis in man. Three years later, Abercrombie[1] described CVT occurring in the puerperium, and since then numerous case reports and series have been published, most of them from autopsy material, leading to the classic description of a rare and severe disease characterized clinically by headache, papilledema, seizures, focal deficits, coma, and death and pathologically by hemorrhagic infarction contraindicating the use of anticoagulants.[5, 7, 25, 37, 54, 57, 71, 93] This early literature and the history of CVT have been extensively covered in two excellent French[37] and English[54] monographs.

In the last 30 years, the introduction and widespread use of cerebral angiography,[58, 68, 105] CT of the brain, and more recently MRI[61, 64, 97] have allowed early diagnosis of CVT, completely modifying our knowledge of this condition.[3, 9] More common than previously thought, CVT is remarkable by its large spectrum of clinical presentation, its highly variable mode of onset, its numerous causes, and its unpredictable but usually favorable outcome. CVT does remain a diagnostic and therapeutic challenge for the clinician, however, because of its often misleading presentation and sometimes difficult treatment.

RELEVANT VENOUS ANATOMY

Blood from the brain is drained by cerebral veins which empty into dural sinuses, themselves drained mostly by internal jugular veins.[17, 37, 43, 48–50, 54]

From the Service de Neurologie, Hôpital Saint-Antoine, Paris, France

Dural Sinuses (Figs. 1 and 2)

The most commonly affected by thrombosis are the superior sagittal sinus, lateral sinuses, cavernous sinuses, and straight sinus.

Superior Sagittal Sinus (SSS). The SSS, triangular in cross-section, lies in the attached border of the falx cerebri. It starts at the foramen cecum and runs backward toward the internal occipital protuberance, where it joins with the straight sinus (SS) and lateral sinuses (LS) to form the torcular Herophili. Its anterior part is narrow or sometimes absent, replaced by two superior cerebral veins that join behind the coronal suture.[54] This is why the anterior part of the sinus is often poorly visualized at angiography and its isolated lack of filling is not sufficient to indicate thrombosis.[57, 58]

The SSS receives superficial cerebral veins and drains the major part of the cortex. It also receives diploic veins, themselves connected to scalp veins by emissary veins, which explains some cases of SSS thrombosis after cutaneous infections or contusions. SSS and other sinuses play a major role in CSF circulation because they contain most of the arachnoid villi and granulations (Pacchionian bodies) in which CSF absorption takes place. The clear-cut consequence is a direct dependency of CSF pressure upon the intracranial venous pressure, accounting for the frequently raised intracranial pressure in SSS thrombosis.

Lateral Sinuses (LS). These extend from the torcular Herophili to jugular bulbs and consist of two portions: the transverse portion, which lies in the

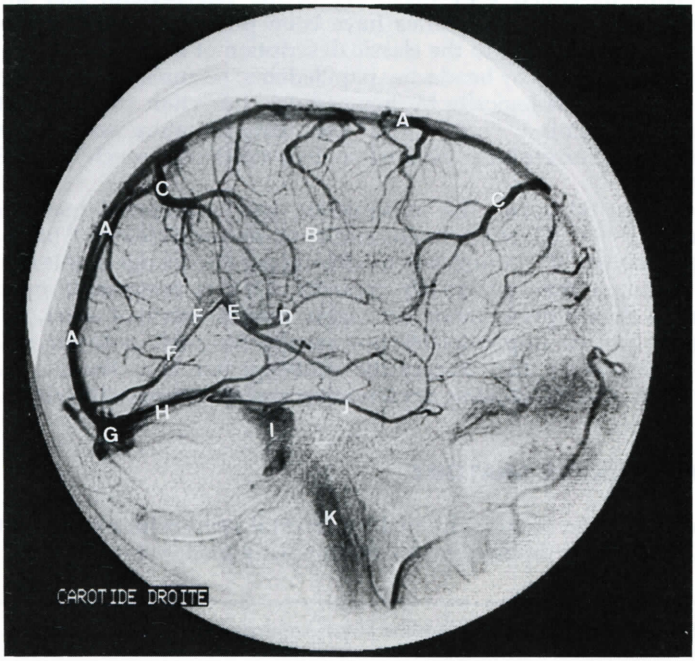

Figure 1. Right carotid angiogram. A = superior sagittal sinus; B = inferior sagittal sinus; C = cortical veins; D = internal cerebral vein; E = great vein of Galen; F = straight sinus; G = torcular herophili; H = lateral sinus, transverse portion; I = lateral sinus, sigmoïd portion; J = vein of Labbe; K = jugular vein.

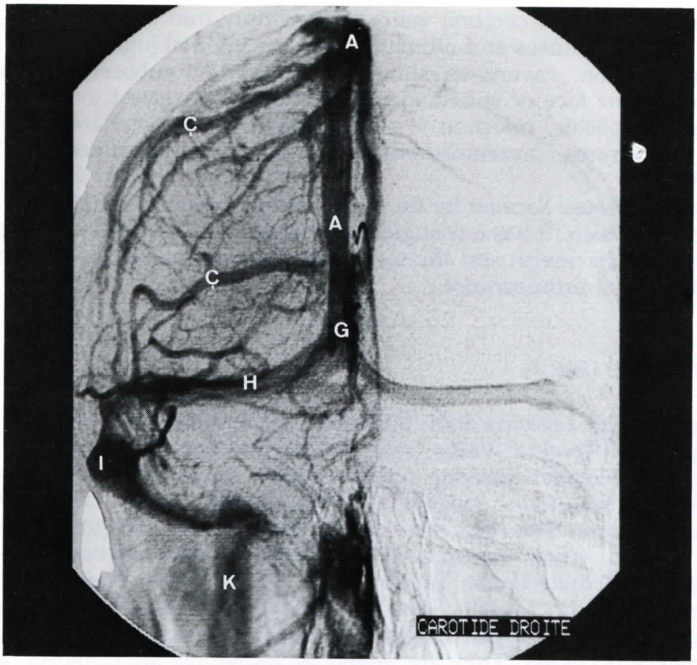

Figure 2. Right carotid angiogram. A = superior sagittal sinus; C = cortical veins; G = torcular herophili; H = lateral sinus, transverse portion; I = lateral sinus, sigmoïd portion; K = jugular vein.

attached border of the tentorium, and the sigmoid portion, which runs on the inner aspect of the mastoid process and is thus susceptible to infectious thrombosis in patients with mastoiditis or otitis media. LS drains blood from the cerebellum, brain stem, and posterior part of the cerebral hemispheres. They also receive some of the diploic veins and some small veins from the middle ear, another possible source of septic thrombosis.

There are numerous LS anatomic variations that may be misinterpreted as sinus occlusion at angiography. In particular, the right LS is frequently larger than the left, which receives most of its supply from the straight sinus. In Hacker's study,[43] the transverse portions were not visualized on ipsilateral carotid angiograms in 14% of cases on the left side and in 3.3% on the right side, whereas sigmoid portions, which may be directly injected via cerebral veins, failed to fill in 4% of cases on the left side and were always demonstrated on the right. An isolated lack of filling of the transverse portion of left LS is thus more suggestive of hypoplasia than thrombosis.

Cavernous Sinuses. Cavernous sinuses consist of trabeculated cavities formed by the separation of the layers of the dura and located on each side of sella turcica, superolaterally to the sphenoid air sinuses. The oculomotor and trochlear cranial nerves, along with the ophthalmic and maxillary branches of the trigeminal nerve, course along the lateral wall of the cavernous sinuses, whereas the abducens nerve and the carotid artery with its surrounding sympathetic plexus are located within the center of the sinus itself.

Cavernous sinuses drain the blood from the orbits through the ophthalmic veins and from the anterior part of the base of the brain by the sphenoparietal

sinus and the middle cerebral veins. They empty into both the superior and inferior petrosal sinuses and ultimately into the internal jugular veins. Because of their situation, cavernous sinuses are often thrombosed in relation to infections of the face or sphenoid sinusitis and, by contrast to other varieties of sinus thrombosis, infection is still the leading cause.[21] Rarely injected on carotid angiograms, cavernous sinuses are now well visualized on CT scans and MRI.

Straight Sinus. Formed by the union of the inferior sagittal sinus and the great vein of Galen, it has a triangular lumen and runs caudally in the junction between the falx cerebri and the tentorium cerebelli to join the torcular at the internal occipital protuberance.

Cerebral Veins (Fig. 1)

Three groups of veins drain the blood supply from the brain:

Superficial Cerebral Veins (or cortical veins). Some of these—the frontal, parietal, and occipital superior cerebral veins—drain the cortex upward into the SSS, whereas others, mainly the middle cerebral veins, drain downward into the cavernous sinuses. These veins are linked by the great anastomotic vein of Trolard, which connects the SSS to the middle cerebral veins, which are themselves connected to the LS by the vein of Labbe. These cortical veins have thin walls, no muscle fibers, and no valves, thereby permitting both dilation and reversal of the direction of blood flow when the sinus in which they drain is occluded. They are linked by numerous anastomoses, allowing the development of a collateral circulation (angiographically visible as "corkscrew" vessels) and probably explaining the good prognosis of some CVT. Since the number and location of cortical veins are inconstant, the angiographic diagnosis of isolated cortical vein thrombosis is extremely difficult and sometimes impossible.

Deep Cerebral Veins. Blood from the deep white matter of the cerebral hemispheres and from the basal ganglia is drained by internal cerebral and basal veins, which join to form the great vein of Galen that drains into the straight sinus. By contrast to the superficial veins, the deep system is constant and always visualized at angiography, so its thrombosis is easily recognized.

Posterior Fossa Veins. The veins of the posterior fossa may be divided into three groups[49, 50]: superior draining into the galenic system, anterior draining into petrosal sinus, and posterior draining into the torcular and neighboring straight and lateral sinuses. They are variable in course, and angiographic diagnosis of their occlusion is extremely difficult.

PATHOLOGY

Pathologic findings have been extensively described in the past.[7, 37, 54] They vary with the site of thrombosis and the interval between the onset of symptoms and death.

The *thrombus* itself is like other venous thrombi elsewhere in the body. When it is fresh, it is a red thrombus rich in red blood cells and fibrin and poor in platelets; when it is old, it is replaced by fibrous tissue sometimes showing recanalization. Its formation is due to the usual pathogenetic factors: venous stasis, increased clotting tendency, changes in the vessel wall, and, less frequently, embolization. Its location and extension are variable. In autopsy

series, extensive thrombosis of SSS and tributary veins is the most frequent finding, but this pattern of involvement no longer reflects the real distribution of CVT.

The consequences of CVT on the brain are again highly variable. The classic picture is that of SSS thrombosis with extensive bilateral hemorrhagic infarcts affecting the cortex and adjacent white matter (Fig. 3). CT scan and MRI studies have now convincingly shown, however, that sinus thrombosis can induce varying degrees of edema without infarction and can even have no detectable effect on the brain.[5]

INCIDENCE

The true incidence of CVT is totally unknown in the absence of specific epidemiologic studies. In most autopsy series, the incidence was found to be extremely low. Ehlers and Courville[25] found only 16 SSS thromboses in a series of 12,500 autopsies, and Barnett and Hyland[7] only 39 noninfective CVT in 20 years. Kalbag and Woolf[54] indicated that CVT was the principal cause of death in only 21.7 persons per year in England and Wales between 1952 and 1961.

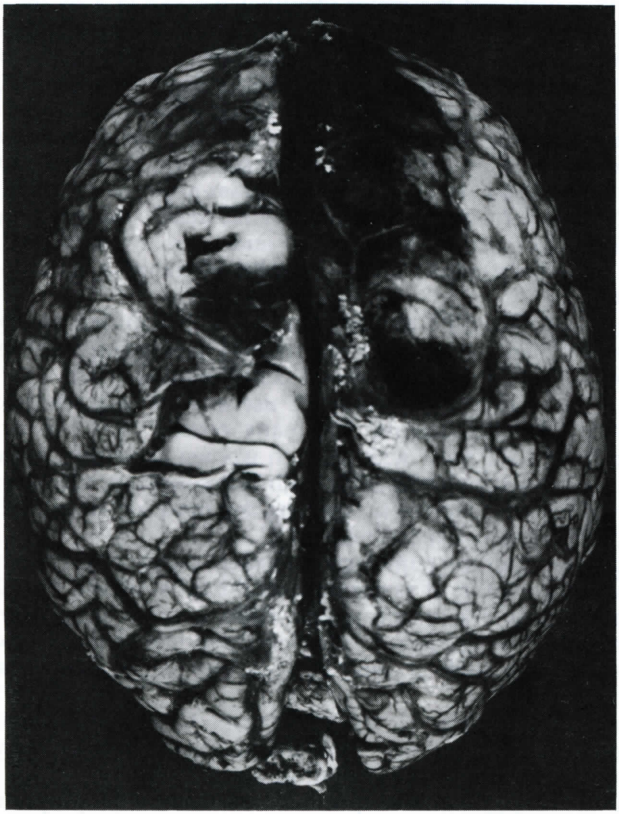

Figure 3. Bilateral hemorrhagic infarctions in superior sagittal sinus (SSS) thrombosis.

By contrast, Towbin[98] found CVT in 9% of 182 consecutive autopsies and Averback,[4] in a series of 7 cases, insists that primary CVT in young adults is an "underrecognized disease." The recent publication of large clinical series[9, 17, 57, 77, 97] suggests that the true incidence is much higher than thought from autopsy series, possibly 10 times higher because the present mortality rate is less than 10%.

It has been suggested that the incidence of CVT is higher in females[29] and in the aged, reflecting the overall greater incidence of thromboembolic diseases in these categories. In our series of 110 cases,[3] the female/male sex ratio was 1.29 and the mean age 38.7 (±14.8 SD). The age distribution was uniform in men, whereas in women 38 cases (61%) occurred between 20 and 35. This probably reflects the frequency of specific causes such as pregnancy and oral contraceptive use in young women.

ETIOLOGY

Numerous conditions can cause or predispose to CVT (Table 1). They include all surgical, gyneco-obstetric, and medical causes of deep vein thrombosis as well as a number of local or regional causes, either infective or noninfective, such as head trauma, brain tumors, and arterial infarcts. Although infection still constituted the major identifiable cause in a recent series (27 of 66),[38] the incidence of septic CVT has greatly diminished in developed countries since the introduction of antibiotics.[21, 91] Thus, in our recent series of 110 cases, only 9 (8.2%) were attributable to infectious causes.[3] Cavernous sinus thrombosis remains the most common form of septic thrombosis, usually following an infection of the middle third of the face due to *Staphylococcus aureus.* Other sites of infection include sphenoid or ethmoid sinusitis, dental abscess, and, less often, otitis media. In chronic forms, gram-negative rods and fungi such as *Aspergillus* species[83] are more commonly isolated.[21] Among general causes, parasitic infections such as trichinosis[30] and more recently HIV and CMV infections[66] have been added to the long list of infective conditions possibly leading to CVT.

In young women, CVT occurs more frequently during puerperium than pregnancy[6, 9, 29, 58, 68] and remains very common in developing countries,[6] whereas in developed countries the role of oral contraceptives (OC)[9, 12, 29, 31, 77] is more important. In our series of 110 cases, OC use was the only etiologic factor in 9 patients (8%).[3] This had led us, like many others,[9, 12, 29, 77] to stop OC and promptly look for CVT (now with MRI) in women presenting with any of the neurologic manifestations compatible with this condition. OC use can also be associated with other conditions, stressing the need for an extensive etiologic work-up, even in young women taking OC.

Among the numerous noninfective medical causes of CVT, malignancies[4, 17, 65, 73, 86] and inflammatory diseases such as Behcet's disease[3, 9] and connective tissue diseases[67, 100] are the most frequent. Although rare, hereditary antithrombin III,[79] protein C,[95] and protein S[19] deficiencies should be systematically looked for in the absence of obvious cause because they imply a family study and a long-term treatment.

In neonates and children, the etiology of CVT is characterized by the frequency of regional infections (otitis, mastoiditis), neonatal asphyxia, severe dehydration, and congenital heart disease.[82]

Despite the continuous description of new causes, the proportion of cases of unknown etiology remains in recent series between 20%[3] and 35%.[38, 97] The

Table 1. CEREBRAL VENOUS THROMBOSIS: RECOGNIZED CAUSES OR PREDISPOSING CONDITIONS

Infective Causes
- *Local*
  - Direct septic trauma[37, 54]
  - Intracranial infection: abscess, empyema, meningitis[9, 37, 38, 54, 57]
  - Regional infections: otitis, tonsillitis, sinusitis, stomatitis, skin[17, 37, 38, 54, 57]
- *General*
  - Bacterial: septicemia,[37, 38, 54, 57] endocarditis,[37, 38, 54, 57] typhoid,[37] tuberculosis[71]
  - Viral: measles,[54] hepatitis,[71] encephalitis,[54] herpes, HIV, CMV[66]
  - Parasitic: malaria,[17] trichinosis[30]
  - Fungal: aspergillosis[83]

Noninfective causes
- *Local*
  - Head injury (open or closed, with or without fracture)[7, 9, 17, 54, 55, 97]
  - Neurosurgical operation[37, 54, 71]
  - Cerebral infarctions and hemorrhages[7, 54]
  - Tumors (meningioma, metastasis, glomus tumor)[37, 54, 64]
  - Porencephaly, arachnoïd cysts[9, 17, 37]
  - Infusions into the internal jugular vein[90]
- *General*
  - Surgical: any surgery with or without deep vein thrombosis[7, 17]
  - Gyneco-obstetric
    - Pregnancy and puerperium[6, 7, 9, 29, 58]
    - Oral contraceptives (estrogens,[9, 29, 77] progestogens[12, 31])
  - Medical
    - Cardiac: congenital heart disease,[17] cardiac insufficiency,[7, 57] pacemaker[39]
    - Malignancies: any visceral carcinoma,[7, 86] lymphoma,[4, 65] leukemia,[17, 65] carcinoid,[73] L-asparaginase therapy[32]
    - RBC disorders: polycythemia,[7] posthemorrhagic anemia,[38] sickle cell disease,[33] paroxysmal nocturnal hemoglobinuria[99]
    - Thrombocythemia (primary or secondary[69])
    - Coagulation disorders: AT_{III},[79] protein C,[95] protein S deficiencies,[19] circulating anticoagulants,[60] disseminated intravascular coagulation,[88] heparin- or heparinoid-induced thrombocytopenia,[52] epsilon-aminocaproïc acid[2] treatment
    - Severe dehydration of any cause[37, 38, 54]
    - Digestive: cirrhosis,[17, 37] Crohn's disease,[11] ulcerative colitis[57, 106]
    - Connective tissue: systemic lupus erythematosus,[100] temporal arteritis,[17] Wegener's granulomatosis[6, 7]
    - Venous thromboembolic disease, Hughes-Stovin syndrome[51]
    - Others: Behçet's disease,[9] sarcoidosis,[15] nephrotic syndrome,[9, 38] neonatal asphyxia,[38] parenteral injections,[27] androgen therapy[85]

Idiopathic

search for a cause thus remains one of the most vexing problems in CVT. It necessitates an extensive initial work-up and, when no cause is found, a long follow-up with repeated investigations.[9]

CLINICAL ASPECTS

CVT presents with a remarkably wide spectrum of symptoms and signs, as illustrated in our series of 110 patients (Table 2). In all series, headache is the most frequent symptom and often the presenting one. In classic series,

Table 2. MAIN NEUROLOGIC SIGNS AND SYMPTOMS IN 110 PATIENTS WITH CEREBRAL VENOUS THROMBOSIS

Headache	83 (75%)
Papilledema	54 (49%)
Motor or sensory deficit	38 (34%)
Seizures	41 (37%)
Drowsiness, mental changes, confusion, or coma	33 (30%)
Dysphasia	13 (12%)
Multiple cranial nerve palsies	13 (12%)
Cerebellar incoordination	3 (3%)
Nystagmus	2 (2%)
Hearing loss	2 (2%)
Bilateral or alternating cortical signs	3 (3%)

From Ameri A: Les thromboses veineuses cérébrales 110 cas. Paris, Thèse, 1991; with permission.

focal deficits (motor or sensory), dysphasia, seizures (partial, generalized status epilepticus), and disorders of consciousness each occur in 50% to 75% of cases,[6, 37, 54, 57] whereas papilledema is less frequent (from 12%[38] to 43%[6]). Inverse tendencies are apparent in our series, with focal deficits, seizures, or disorders of consciousness in about a third of cases and papilledema in half. Although there might be a selection bias in our series because of an important referral from ophthalmologists, the main reason for this changing pattern is most probably the possibility of early diagnosis now offered by neuroimaging techniques in patients presenting with headache. It is thus remarkable that the famous classic picture of SSS thrombosis with bilateral deficits, seizures, and coma was encountered in only three of our patients.

The mode of onset of symptoms is also highly variable: In our series of 110 patients,[3] it was acute (less than 48 hours) in 31 patients (28%), subacute (more than 48 hours but less than 30 days) in 46 (42%), and chronic (more than 30 days) in 33 (30%). Acute onset is more frequent in infectious or obstetric CVT and when focal signs are frequent, whereas chronic onset is more frequent in inflammatory diseases, in idiopathic cases, or in the absence of focal signs.

With such a wide spectrum of neurologic signs and modes of onset, the clinical presentation of CVT is extremely variable. It can be separated into four groups: those with isolated intracranial hypertension, those with focal cerebral signs, those with the cavernous sinus syndrome, and those with unusual presentations.

Isolated intracranial hypertension with headache and papilledema, mimicking benign intracranial hypertension (pseudotumor cerebri), is the most homogeneous pattern, accounting for 40% of our 110 patients. Despite the fact that SSS and LS thrombosis have long been recognized as one of its leading causes,[42, 93] benign intracranial hypertension has, in numerous reports, been diagnosed purely on clinical, CSF, and CT findings. Because CVT can mimic all the features of benign intracranial hypertension,[9, 97] normal four-vessel angiography or normal MRI should be added to the classic diagnostic criteria of this syndrome.[18] Thus, in a prospective study of 24 consecutive patients presenting with benign intracranial hypertension, angiography disclosed CVT in 6.[96]

The second group, characterized by the presence of **focal cerebral signs,** is the largest, accounting for roughly 75% of published cases, but it is an heterogeneous one, depending upon the mode of onset of focal signs, their

nature (deficits, seizures, or both), and their possible association with altered consciousness. Acute cases simulate an arterial stroke, chronic ones simulate tumors, and subacute cases mimic encephalitis or abscess. Focal signs can be even more misleading when they present like transient ischemic attacks[9] or migraine-like phenomena.[70]

Cavernous sinus thrombosis has a distinctive clinical picture[17, 21, 37, 38, 59, 91] that includes, in classic acute cases, chemosis, proptosis, and painful ophthalmoplegia, initially unilateral but frequently becoming bilateral. Dramatic complications can occur such as extension to other sinuses[88] and stenosis of the intracavernous portion of the internal carotid arteries.[21] Cavernous sinus thrombosis is not always acute, however, but can also take a more indolent form (either spontaneously or because of the masking effect of an inadequate antibiotic regimen), with an isolated abducens nerve palsy and only mild chemosis and proptosis leading to great diagnostic difficulties.[21]

The grouping of signs of CVT into these three main patterns (isolated intracranial hypertension, focal signs, and cavernous sinus syndrome) does not account for every case. Some patients with isolated intracranial hypertension later develop focal neurologic signs.[9, 33] Others initially present with isolated headache, grand mal seizures, or psychiatric disturbances. Others present with headache of sudden onset, neck stiffness, and CT scan or lumbar puncture evidence of subarachnoid hemorrhage simulating a ruptured intracranial aneurysm.[9] Finally, CVT may be so insidious that it is discovered only at postmortem examination, particularly in elderly patients dying of congestive heart failure.[7] It can even be totally asymptomatic, as recently shown in a patient given a routine CT scan after mastoidectomy which showed a left LS thrombosis.[41]

TOPOGRAPHIC DIAGNOSIS

Thrombosis most frequently affects (in order of decreasing frequency) SSS, LS, and cavernous sinus. The location of venous thrombosis in our 110 patients is indicated in Table 3. It shows that SSS (72%) and LS (70%) are the sinuses most frequently involved, but rarely in isolation (23%). In most cases, thrombosis affects several sinuses or sinuses and cerebral veins. Thrombosis of the galenic system is rare, with some 50 reported cases and 9 in our series. Only a few cases have been described of petrosal sinus,[37] isolated cortical,[36] or cerebellar vein[9] thrombosis, but these conditions might be underdiagnosed because of the extreme difficulty of diagnosis.

The frequent association of sinus and cerebral vein thrombosis explains the lack of well-defined topographic clinical syndroms, similar to those described in arterial occlusions. Thus, SSS thrombosis can present with any of the above described patterns; this also applies to LS thrombosis, in which isolated intracranial hypertension is probably even more frequent and, among focal signs, dysphasia is not unusual.[9] Thrombosis of the petrosal sinuses was described in the old literature[37, 94] and was characterized mainly by a fifth nerve palsy for the superior sinus and by a sixth nerve palsy for the inferior one. As already stressed, angiographic diagnosis of isolated cortical vein thrombosis is extremely difficult,[36] but there are old reports of anatomic or surgical cases in patients presenting with an acute or rapid onset of focal deficits, seizures, or both.[23, 37] The classic picture of deep cerebral venous thrombosis is that of an acute coma with decerebration or extrapyramidal hypertonia leading to death in a few days or resolving, but with heavy sequelae such as akinetic mutism,

Table 3. SITE OF VENOUS OCCLUSION IN 110 PATIENTS WITH CEREBRAL VENOUS THROMBOSIS

Superior sagittal sinus (SSS)	79 (72%)
Lateral sinuses (LS)	78 (70%)
Right	29 (26%)
Left	29 (26%)
Both	20 (18%)
Straight sinus (SS)	16 (14.5%)
Cavernous sinus	3 (2.7%)
Cerebral veins	42 (38%)
Superficial	30 (27%)
Deep	9 (8%)
Cerebellar veins	3 (3%)
One sinus only	25 (23%)
SSS	14 (13%)
LS	10 (9%)
SS	1 (1%)
Deep veins only	1 (1%)
Isolated cortical veins	2
Sinuses plus cerebral or cerebellar veins	39 (35%)

From Ameri A: Les thromboses veineuses cérébrales 110 cas. Paris, Thèse, 1991; with permission.

dementia, bilateral athetoid movements, vertical gaze palsy, and dystonia.[8, 25, 37, 53] Recent reports have illustrated benign forms presenting mainly with confusion.[9, 26, 45] The few reported cases of cerebellar vein thrombosis are mainly anatomic,[28, 71] but we reported a patient presenting with a 3-month history of cranial nerve palsies, cerebellar incoordination, and papilledema simulating a posterior fossa tumor,[9] and a somewhat similar case has been recently published.[78]

INVESTIGATIONS

Computed Tomography Scan (Table 4)

CT scan with and without contrast injection is the first neuroimaging examination to carry out when CVT is clinically suspected, both to rule out

Table 4. CT SCAN IN 91 PATIENTS WITH CEREBRAL VENOUS THROMBOSIS

Empty delta sign	19 (21%)
Contrast enhancement of falx or tentorium	17 (19%)
Small ventricles	47 (52%)
Enlarged ventricles	3 (3%)
Spontaneous hyperdensity	18 (20%)
Hypodensity	30 (33%)
Gyral enhancement	23 (25%)

From Ameri A: Les thromboses veineuses cérébrales 110 cas. Paris, Thèse, 1991; with permission.

other conditions and to try to confirm CVT. CT findings have been described in detail in numerous reports[11, 13, 14, 16, 35, 41, 56, 75, 84, 104] and are now well established.

Three abnormalities are considered direct signs of CVT: the cord sign, the dense triangle, and the delta or empty triangle sign.

The *cord sign*, visible on unenhanced CT scans, represents the visualization of a thrombosed cortical vein[13, 35, 75]; it is extremely rare and its diagnostic value is debated.[16]

The *dense triangle* also reflects spontaneous SSS opacification by freshly congealed blood[14, 72]; it is thus a very early sign, again extremely rare, present in less than 1 of 50 cases. It is difficult to assess, particularly in other sinuses (lateral and straight sinus), which can be spontaneously hyperdense in normal children or in patients with hemoconcentration.[72]

The *empty delta sign*, described by Buonanno et al,[13] appears after contrast injection and reflects the opacification of collateral veins in the SSS wall, contrasting with the noninjection of the clot inside the sinus (Fig. 4). It is the most frequent direct sign, present in approximately 30% of published cases.[14, 75, 84, 104] It is absent, however, when thrombosis does not affect the posterior third of SSS or when CT scan is performed in the first 5 days after onset of symptoms or more than 2 months later.[84] Its sensitivity and specificity are increased with some technical refinements,[35, 41, 75] but it is found in only 10% to 20% of CT scans routinely performed.[9, 16] Furthermore, it is not pathognomonic because the early division of the SSS can be responsible for a false delta sign.[72]

CT scan can also be useful in demonstrating cavernous sinus thrombosis showing on postcontrast CT as multiple irregular filling defects with bulging cavernous sinuses and enlarged orbital veins.[20]

Indirect and nonspecific abnormalities are more frequent:

Intense contrast enhancement of falx and tentorium[13, 14, 75] is present in some 20% of cases.[16] It is easily recognized in the tentorium but can be difficult to assess in the falx, particularly in aged patients. It indicates venous stasis or hyperemia of the dura mater. Tentorial enhancement is usually thought to suggest straight sinus thrombosis,[75] but it is not rare in SSS thrombosis.[16]

A common finding is the presence of small ventricles with swelling and sometimes diffuse low density suggestive of edema.[9, 13, 16, 56, 75] Although reported in 20% to 50% of cases, it is nonspecific and frequently difficult to differentiate from normal brain, particularly in the young. In some cases the cerebral swelling can be confirmed by the later increase in size of ventricles that were initially small.[56]

Usually described by pathologists as hemorrhagic, venous infarcts on CT scan present with a spontaneous hyperdensity in 10% to 50% of cases.[11, 14, 16, 75] Two main aspects are encountered: large, often multifocal, hematomas and petechial hemorrhages[16] (Fig. 5). Nonhemorrhagic venous infarcts are more frequent and protean in appearance[16, 75]: focal hypodensity with gyral enhancement (Fig. 6), areas of hypodensity without enhancement, isolated gyral enhancement. Hemorrhagic or nonhemorrhagic infarcts can be unilateral or bilateral, single or multiple. They are seen superficially in the hemispheres in SSS thrombosis and within the basal ganglia in deep venous system thrombosis.[13, 14, 16, 75]

In 10% to 20% of cases (26% in our present series[3]) CT scan is normal in patients with proven CVT and more frequently so in patients presenting with isolated intracranial hypertension.[3, 16, 75]

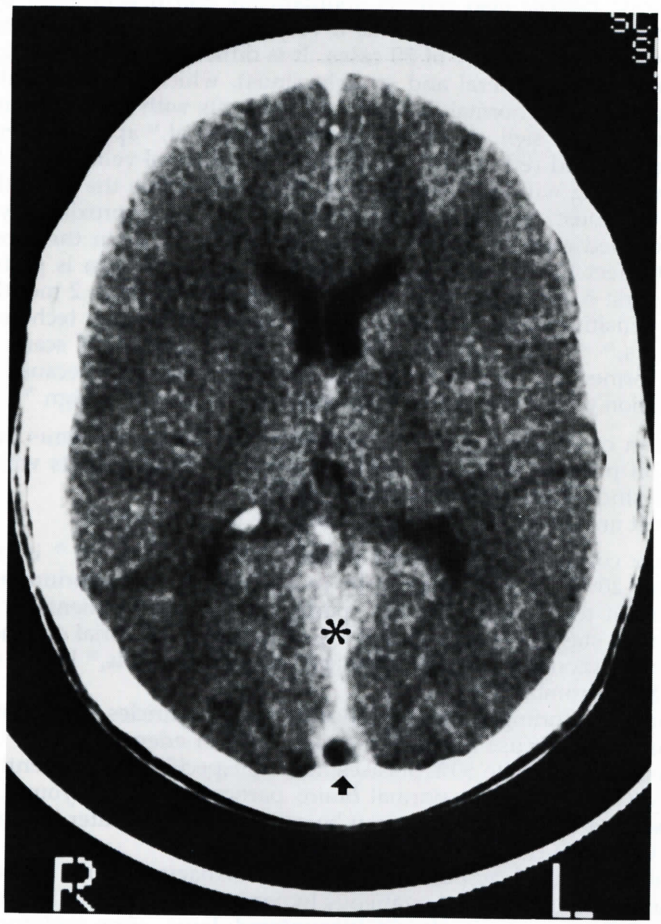

Figure 4. Enhanced CT scan. Empty delta sign indicated by *arrow*. Falx enhancement indicated by *asterisk*.

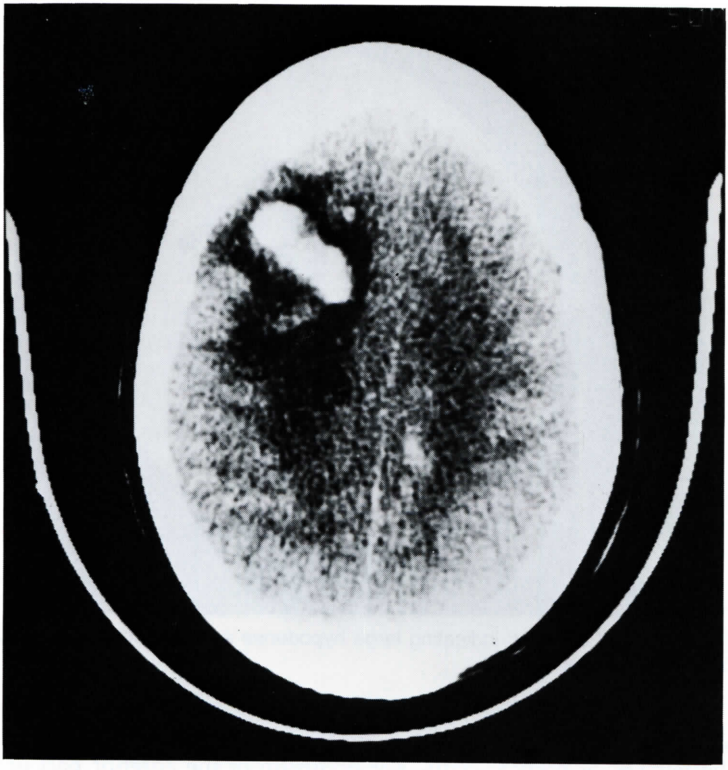

Figure 5. SSS thrombosis with large bilateral hypodensities and bilateral areas of hyperdensity, highly suggestive of hemorrhagic infarctions.

In summary, the place of CT scan in the diagnostic strategy for CVT is of crucial importance because CT scan rules out other conditions such as arterial stroke, abscess, tumors, and subarachnoid hemorrhage. It should therefore be performed, without and then with contrast, at the earliest clinical suspicion of CVT. Nevertheless, because it may be normal or show nonspecific changes, angiographic and MRI confirmation should be obtained in all cases lacking pathognomonic CT changes.

Angiography

Angiography has been the key procedure in diagnosis of CVT for many years and still remains the gold standard for evaluation of new methods. It requires a perfect technique: four-vessel angiography (conventional or digitalized intra-arterial) with visualization of the entire venous phase on at least two projections (frontal and lateral) and three if possible, oblique views being the best to entirely visualize the SSS.[9, 58, 68, 103, 105]

The partial or complete lack of filling of veins or sinuses is the best angiographic sign of CVT. Easily recognized when it affects the posterior part or the entire SSS (Fig. 7), both LS (Fig. 8), or the deep venous system, it may

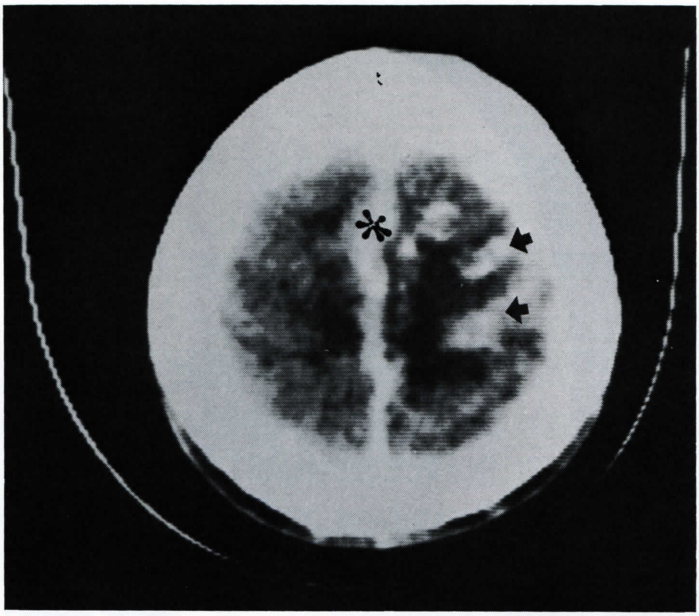

Figure 6. Enhanced CT scan indicating large hypodense area with intense gyral (*arrows*) and falx (*asterisk*) enhancement.

be more difficult to interpret in other locations such as the anterior third of the SSS, the left LS, or cortical veins. For occlusion of the anterior part of SSS to be established, it is necessary to have either involvement of another sinus or nonequivocal indirect signs of CVT such as delayed emptying and dilated collateral veins. For LS thrombosis, the main argument is the absence of filling of the totality of the sinus or of its sigmoid portion, contrasting with the presence of the sinus groove and normality of the jugular foramen on plain radiographs of the skull. Isolated cortical vein thrombosis is difficult and sometimes impossible to detect, except when the partly visualized vein stops suddenly and is surrounded by dilated collateral veins. In all doubtful cases, MRI is of considerable value: It shows thrombosis as an increased signal in a vessel not visualized at angiography.[63]

Other angiographic findings include delayed emptying and development of collateral venous pathways, found in 50% of cases, particularly in SSS thrombosis.[9, 58, 68] Dilated and tortuous cortical collateral veins with a corkscrew appearance (Fig. 7) are much more frequent than transcerebral or intradural collaterals.

Magnetic Resonance Imaging

MRI offers major advantages for the evaluation of patients suspected of CVT because of its sensitivity to blood flow, its ability to visualize the thrombus itself, and its noninvasiveness. It is, at present, the method of choice for the diagnosis and follow-up of CVT, angiography being required only in difficult

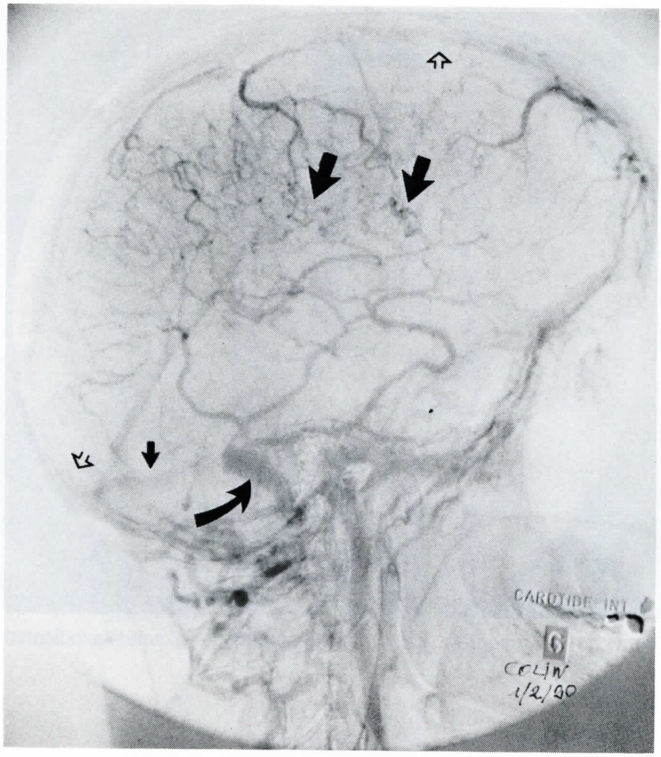

Figure 7. Left carotid angiogram. Total SSS occlusion (*open arrows*) with dilated cortical veins (*large arrows*) (cork-screw veins). Transverse portion of lateral sinus is not injected (*small arrow*). Sigmoïd portion (*curved arrow*) is injected through collateral cortical veins.

or doubtful cases. A variety of MR findings have been described, mainly related to the evolution of thrombosis.[45, 61, 80, 89, 94, 97] At a very early stage, there is an absence of flow void and the occluded vessel appears isointense on T1-weighted images and hypointense on T2-weighted images. A few days later, the absence of flow void persists but the thrombus becomes hyperintense, initially on T1 and then on T2-weighted images (Fig. 9). These changes represent the aging of the thrombus, with biochemical conversion of oxyhemoglobin to methemoglobin. Late changes (approximately 2 weeks after onset) can reveal the beginning of vascular recanalization with the resumption of flow void. In our series, 28 patients had an MRI study. The most common pattern is an increased signal both in T1- and T2-weighted images (12 cases), and the T2 signal is twice as frequently increased (24/12) as the T1 and changes less rapidly with time. T1-weighted images were normal in 5 cases between day 10 and day 30, and after 30 days there was an isosignal in six and a normal flow void in five. MRI diagnosis is particularly easy in SSS thrombosis,[3, 61, 97] but convincing images have also been obtained in cases of thrombosis involving LS,[63, 64, 89] straight sinus[80, 89] (Fig. 10), internal cerebral veins and vein of Galen,[45, 61] cavernous sinus,[80] and cortical veins.[80] Besides its ability to detect thrombosis, MRI also offers the advantages of sometimes showing parenchymal lesions not visible

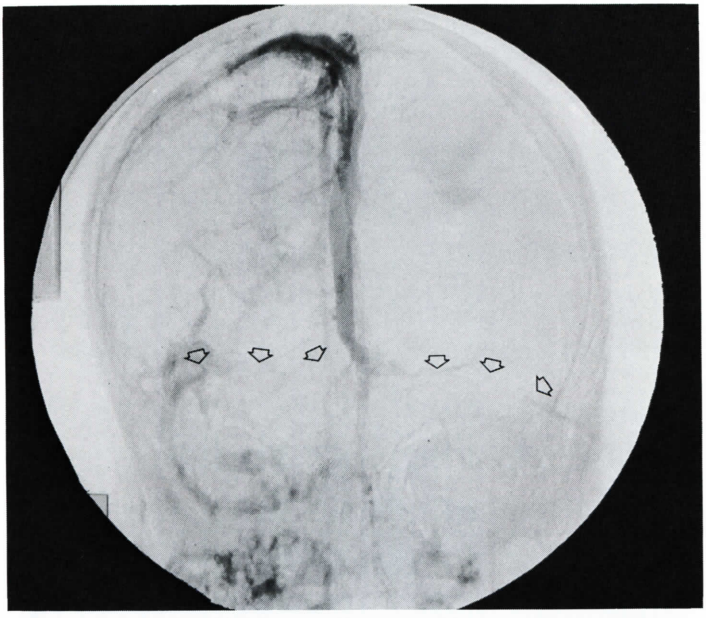

Figure 8. Right carotid angiogram. Lack of filling of both lateral sinuses indicated by *arrows*.

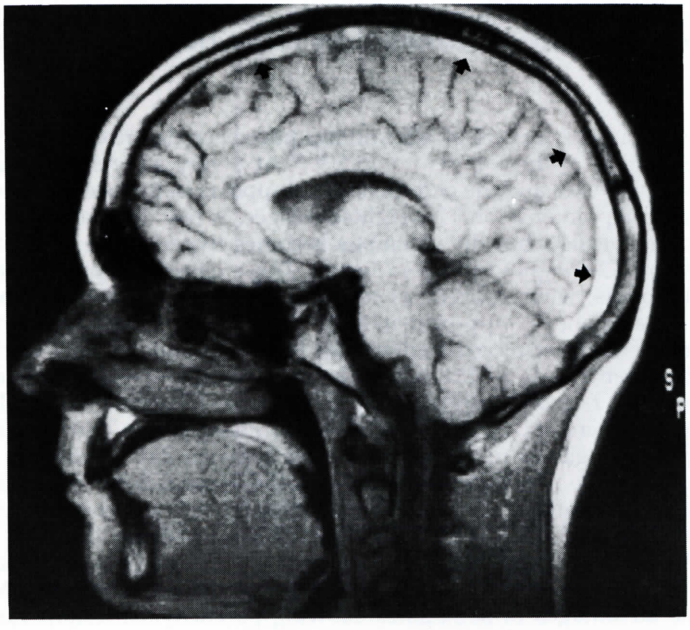

Figure 9. MRI scan of T1-weighted hypersignal indicating SSS thrombosis (*arrows*).

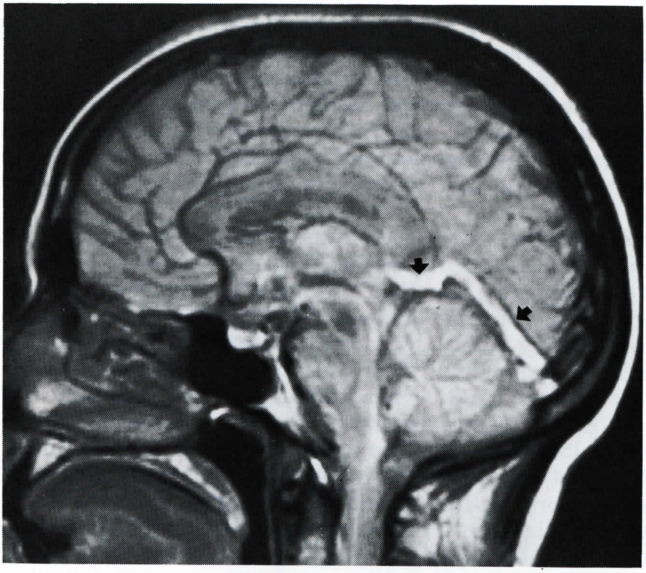

Figure 10. MRI scan of T2-weighted (first echo) hypersignal indicating vein of Galen and straight sinus thrombosis (*arrows*).

on CT scan and of demonstrating an underlying cause such as an adjacent tumor or unsuspected mastoiditis.[64]

In some cases, however, interpretation of MR images, particularly for LS and cortical veins, is not so easy because of false-negative or false-positive images.[3, 64, 94, 97] With high field strength, the very early decreased signal of thrombosis observed on T2-weighted images may be confused with patency. It may then be necessary to repeat MR examination a few days later or to image the patient again at intermediate field strength. An increased signal mimicking thrombosis can be artifactually created by slowly flowing blood. Repositioning the patient, repeating the sequence in a different plane, using at least two sequences, and sometimes obtaining specialized studies are helpful to eliminate these artifacts.[61, 94] Another disadvantage of MRI techniques used so far has been that the venous system is not seen coherently, as it is in angiography, but on different slices. Three-dimensional MR flow imaging has overcome this shortcoming, and convincing images of SSS thrombosis have been published.[102] This new technique offers theoretical advantages over angiography: it allows reconstruction from different angles, it is noninvasive, does not require contrast injection, and can be coupled with spin-echo imaging that shows the vessels and the parenchymal lesions at the same time.

Other Investigations

CSF examination can still be a useful diagnostic tool because it is often (10%) abnormal in composition or in pressure.[9, 17, 37, 54, 57] Abnormalities in composition include increased protein content and presence of red blood cells in two thirds of cases and pleocytosis in one third. Mainly seen when focal signs are present,

pleocytosis and presence of red blood cells can also be found in patients presenting with "benign intracranial hypertension," pointing to sinus thrombosis as the possible cause of this syndrome.[9] Although CSF study in the CT scan and MRI era has become obsolete in most cases of nonseptic CVT presenting with focal signs, it remains necessary in patients presenting with isolated intracranial hypertension and normal CT scan, to rule out meningitis, to confirm the increase in CSF pressure, and to remove CSF when vision is threatened.

Other investigations are of less interest: EEG is abnormal in roughly 75% of cases,[9] but changes are nonspecific. The most common pattern is a severe generalized slowing more marked on one side with frequent superimposed epileptic activity. In some patients with focal symptoms, it is useful in showing a generalized slowing indicating a more diffuse lesion than clinically suspected.

Isotope brain scanning with ^{99m}Tc was able to detect SSS and LS occlusion.[40] Some false negatives have been reported, however, probably owing to the visualization of an intense collateral circulation in the sinus walls. A case has recently been published of SSS thrombosis demonstrated by indium-111 platelet scintigraphy,[10] but this technique requires that images be taken at 24 and 48 hours after injection, which limits its use on an emergency basis.

General investigations are directed toward demonstrating the underlying cause. Because of the multiplicity of etiologies, this is a long and difficult task whenever the cause is not clinically evident. The presence of fever, increased erythrocyte sedimentation rate, or increased polymorphonuclear leukocytes points to infective, inflammatory, or malignant causes. Even with such underlying diseases, these abnormalities are sometimes lacking and, by contrast, they are occasionally found in idiopathic cases.[3, 9]

Detailed coagulation studies have only rarely been performed in series of CVT, and their results have been conflincting. Some have found a "hypercoagulability state,"[74] an increase in platelet adhesiveness and aggregability,[6] and a decrease in fibrinolytic activity,[6] but this was during pregnancy and puerperium or in women taking oral contraceptives. Others did not confirm these results[29] or found merely an increased platelet aggregation with the lowest dose of epinephrine.[9] On the whole, there is no point in performing detailed hemostasis studies routinely in all patients with CVT, but these investigations are necessary in all apparently "idiopathic" cases and in patients with a personal or familial history of recurrent venous thrombosis in order to detect possible causative conditions such as protein C,[95] protein S,[19] or antithrombin III[79] deficiencies.

OUTCOME

Before the introduction of angiography, CVT was diagnosed mainly at autopsy and therefore thought to be most often lethal.[7, 37, 54, 71] In early angiographic series, mortality still ranked between 30% and 50%,[57] but in more recent series, it was between 5.5%[3] and 30%.[9, 97, 104]

Factors classically considered to indicate poor prognosis are the rate of evolution of thrombosis,[54] the presence of coma,[57] the age of patients (with a high mortality rate in infancy and in the aged),[54] the presence of focal symptoms,[9, 37, 54] the presence of an hemorrhagic infarct, and an empty delta sign on CT scan.[104] The two main prognostic factors are (1) the topography of cerebral veins, deep cerebral vein thrombosis and cerebellar vein thrombosis carrying a much higher risk than cortical vein thrombosis,[8, 25, 26, 37, 57] and (2) the

underlying cause: Septic CVT still has a mortality rate of 30% in cavernous sinus thrombosis and up to 78% in SSS thrombosis.[24] In our series of 110 patients, the 6 deaths occurred in patients who had severe underlying causes such as subdural empyema, brain abscess, end-stage systemic lupus erythematosus, and carcinomatous meningitis.

It has long been recognized that, if survival occurs in CVT, the prognosis for recovery of function is much better than in arterial thrombosis, with a minority (15%–25%) of patients left with sequelae such as optic atrophy or focal deficits.[9, 17, 97, 104] In our series, 77% of patients made a complete recovery and 17% had sequelae.[3]

The prognosis is highly variable and remains unpredictable for a given patient. Acute cases can have a fulminating course leading to death in a few days or completely recovering. Chronic cases can worsen progressively, leading to sequelae, whereas others recover spontaneously. There are extremely benign forms limited to TIA or headache or epilepsy which are probably still underrecognized. On the whole, isolated sinus thrombosis carries a good prognosis, but can at any moment extend to cerebral veins and then possibly lead to death or sequelae.

Very little is known about the long-term outcome of patients with CVT.[9, 47] A few reports suggest than LS thrombosis can later induce arteriovenous malformations affecting the transverse sinus.[47] Residual epilepsy and recurrences of CVT (six in our study)[3] seem uncommon, but this would have to be documented by long-term prospective studies.

TREATMENT

The variability in the natural history of an infrequent disease explains why treatment is still controversial. It is based on an individualized combination of symptomatic medications (anticonvulsants, antibiotics, methods to reduce intracranial pressure) and antithrombotic treatments.

As far as anticonvulsant treatment is concerned, some favor its systematic use,[54] whereas the majority restrict it to patients who present with seizures.[9] The question of the duration of treatment remains open: In our series, it was progressively discontinued 2 years after CVT, but only in patients with normal EEG and CT scan who had neither recurrent seizures nor neurologic sequelae.[9]

In septic CVT, all agree on the use of a wide spectrum combination of antibiotics, such as a penicillinase-resistant penicillin together with a last generation cephalosporin and metronidazole (or chloramphenicol), as a reasonable initial regimen. This treatment may be subsequently modified by culture results and should be given over a period of at least 2 weeks.[21, 24]

Opinions are more divergent on methods to reduce intracranial pressure and diverse approaches have been used: steroids,[9, 17, 38, 77, 97] mannitol,[9, 17, 33, 38] acetazolamide,[9, 17, 33, 77] daily lumbar punctures,[9, 17, 33] ventricular cerebrospinal fluid drainage,[33, 46] lumbar peritoneal shunting,[9] a barbiturate-induced coma,[33, 41, 46] LS venous bypass,[87] or even craniectomy.[77] In our series of 110 patients, only 3 required shunting procedures; in all others, the combination of antiedema agents, acetazolamide, and repeated lumbar punctures was sufficient to control raised intracranial pressure. As long as vision does not deteriorate and consciousness remains normal, such a conservative approach seems reasonable in a condition in which spontaneous recovery is the rule.[6, 9, 17, 64, 77, 80, 97]

The treatment of the thrombotic process is still debated. Surgical thrombectomy has been performed in some patients,[29] but an overwhelming majority oppose direct surgery, which might be harmful on a swollen and sometimes hemorrhagic brain.[1, 17, 22, 57, 77]

The use of anticoagulants has long remained controversial because of the risk of further bleeding into an already hemorrhagic infarct; such a complication has been well documented.[7, 12] The risk of increasing intracranial haemorrhage has probably been overestimated, however, and an increasing number of observations favor the use of heparin. (1) There are a number of well-documented cases in which a dramatic improvement occurred 24 hours after the initiation of heparin, sometimes followed by a worsening when high-dose heparin was changed to oral anticoagulants and by a quick improvement again after full-dose heparin therapy was resumed.[9, 31, 97] (2) Heparin has been used in many patients since the pioneer observations of Martin and Sheenan[62] and Stansfield[92] without deleterious effect.[3, 9, 17, 31, 44, 57, 59, 77, 97] In our series, 82 patients were treated with heparin and no death or worsening was observed.[3] This being partly a retrospective study, no definite conclusion can be drawn, but it indicates that, at least in this group, heparin was not harmful. (3) The benefit of heparin has been demonstrated in the only randomized trial so far performed in CVT[101]: High-dose intravenous heparin was compared to placebo in patients with angiographically proven CVT. The study had to be stopped after the first 20 patients because of a statistically significant difference in favor of heparin ($P < 0.05$). After 3 months, all 10 heparin-treated patients had either completely recovered or were left with only a slight neurologic deficit, whereas 4 patients in the control group died or had severe sequelae.

There is thus good evidence that heparin is beneficial in patients with CVT, but there is still disagreement on the best indications. All would agree that heparin is indicated in patients with coexistent pelvic or deep leg vein thrombosis and those with an increased thrombotic tendency. By contrast, heparin is usually contraindicated in CVT caused by paroxysmal nocturnal hemoglobinuria because of frequent thrombocytopenia.[99] When there is no formal indication or contraindication due to underlying or associated conditions, the use of anticoagulants is still controversial in a disease that recovers spontaneously in a majority of cases but can also—although exceptionally—lead to fatal hemorrhage. For the majority, high-dose heparin is now the drug of choice in CVT, provided that there is no hemorrhagic infarction on CT scan.[38, 44, 77] Nevertheless, there are several reports of patients with hemorrhagic infarcts who did improve on anticoagulants,[9, 41] and in the German randomized study heparin was found beneficial even in such patients.[101] Our approach at present is to anticoagulate all patients with demonstrated CVT, provided that there is no general contraindication to the use of heparin. Low molecular weight heparin might prove as effective as conventional heparin, but experience is still limited.[34] The duration of anticoagulant treatment is not standardized. By analogy with deep vein thrombosis, we have been using heparin for the first few days and oral anticoagulants for the next 2 to 3 months except when there is a known thrombotic tendency, for which treatment is prolonged as necessary.

The use of fibrinolytics is even more controversial. They were found by some[77] to be dangerous because of bleeding into the infarct and by others to be beneficial by preventing extension of thrombosis and promoting recanalization.[103] Urokinase infusion was recently performed locally inside the SSS in a single anectotal case report.[81] There is at present no scientific reason to treat CVT patients with fibrinolytics (even t-PA) rather than with heparin, but there

is possibly a case for a randomized trial to compare these two treatment regimens.

References

1. Abercrombie J: Pathological and Practical Researches of the Brain and Spinal Cord. Edinburgh, John Carfral and Son, 1828, p 26
2. Achiron A, Gornish M, Melamed E: Cerebral sinus thrombosis as a potential hazard of antifibrinolytic treatment in menorrhagia. Stroke 21:817–819, 1990
3. Ameri A: Les thromboses veineuses cérébrales 110 cas. Paris, Thèse, 1991, p 150
4. Averback P: Primary cerebral venous thrombosis in young adults. The diverse manifestations of an underrecognized disease. Ann Neurol 3:81–86, 1978
5. Bailey OT, Hass GM: Dural sinus thrombosis in early life, clinical manifestations and extent of brain injury in acute sinus thrombosis. J Pediatr 11:755–771, 1937
6. Bansal BC, Gupta RR, Prakash C: Stroke during pregnancy and puerperium in young females below the age of 40 years as a result of cerebral venous/sinus thrombosis. Jpn Heart J 21:171–183, 1980
7. Barnett HJM, Hyland HH: Non infective intracranial venous thrombosis. Brain 76:36–49, 1953
8. Bots GAM: Thrombosis of the galenic system veins in the adult. Acta Neuropathol 17:227–233, 1971
9. Bousser MG, Chiras J, Sauron B, et al: Cerebral venous thrombosis. A review of 38 cases. Stroke 16:199–213, 1985
10. Bridgers SL, Strauss E, Smith EO, et al: Demonstration of superior sagittal sinus thrombosis by indium-111 platelet scintigraphy. Arch Neurol 43:1079–1081, 1986
11. Brismar J: Computed tomography in superior sagittal sinus thrombosis. Acta Radiol (Stockh) 21:321–326, 1980
12. Buchanan DS, Brazinsky JH: Dural sinus and cerebral venous thrombosis. Incidence in young women receiving oral contraceptives. Arch Neurol 22:440–444, 1970
13. Buonanno F, Moody DM, Ball MR, Laster DW: Computed cranial tomographic findings in cerebral sino-venous occlusion. J Comput Assist Tomogr 2:281–290, 1978
14. Buonanno FS, Moody DM, Ball RM: CT scan findings in cerebral sinovenous occlusion. Neurology 12:288–292, 1982
15. Byrne JV, Lawton CA: Meningeal sarcoïdosis causing intracranial hypertension secondary to dural sinus thrombosis. Br J Radiol 56:755–757, 1983
16. Chiras J, Bousser MG, Meder JF, et al: CT in cerebral thrombophlebitis. Neuroradiology 27:145–154, 1985
17. Coquillat G, Warter JM: Thromboses veineuses cérébrales. Rapport de neurologie présenté au Congrès de psychiatrie et de Neurologie de langue française. Paris, Masson, 1976
18. Corbett JJ: Problems in the diagnosis and treatment of pseudo-tumor cerebri. Can J Neurol Sci 10:221–229, 1983
19. Cros D, Comp PC, Beltran G, Gum G: Superior sagittal sinus thrombosis in a patient with protein S deficiency. Stroke 21:633–636, 1990
20. Deslegte RGM, Kaiser MC, Vanderbaan S, Smit L: Computed tomographic diagnosis of septic sinus thrombosis and their complications. Neuroradiology 30:160–165, 1988
21. Dinubile MJ: Septic thrombosis of the cavernous sinuses. Neurological review. Arch Neurol 45:567–574, 1988
22. DiRocco C, Lanelli A, Leone G, et al: Heparin-urokinase treatment in a septic dural sinus thrombosis. Arch Neurol 38:431–435, 1981
23. Dowman CE: Thrombosis of the rolandic vein. Arch Neurol Psychiatry 15:110–112, 1926
24. Editorial: Infections of the dural venous sinuses. Lancet 1:201–202, 1987
25. Ehlers H, Courville CB: Thrombosis of internal cerebral veins in infancy and childhood. Review of literature and report of five cases. J Pediatr 8:600–623, 1936

26. Eick JJ, Miller KD, Bell KA, Tutton RH: Computed tomography of deep cerebral venous thrombosis in children. Radiology 140:399–402, 1981
27. Eikmeier G, Kuhlmann R, Gastpar M: Thrombosis of cerebral veins following intravenous application of clomipramine. J Neurol Neurosurg Psychiatry 52:1461, 1989
28. Eng LJ, Longstreth WT, Shaw CM, et al: Cerebellar venous infarction: Case report with clinicopathologic correlation. Neurology 40:837–839, 1990
29. Estanol B, Rodriguez A, Conte G, et al: Intracranial venous thrombosis in young women. Stroke 10:680–684, 1979
30. Evans RW, Patten BM: Trichinosis associated with superior sagittal sinus thrombosis. Ann Neurol 11:216–217, 1982
31. Fairburn B: Intracranial venous thrombosis complicating oral contraception: Treatment by anticoagulant drugs. Br Med J 2:647, 1973
32. Feinberg WM, Swenson MR: Cerebrovascular complications of L-asparaginase therapy. Neurology 38:127–133, 1988
33. Feldenzer JA, Bueche MJ, Venes JL, Gebarski SS: Superior sagittal sinus thrombosis with infarction in sickle cell trait. Stroke 18:656–660, 1987
34. Fevrier MJ, Nguyen JP, Brugieres P, Goujon C: Thrombophlébite du sinus longitudinal supérieur au stade chirurgical. A propos d'un cas. Intérêt de l'Héparine de bas poids moléculaire. Neurochirurgie 33:490–493, 1987
35. Ford K, Sarwar M: Computed tomography of dural sinus thrombosis. Am J Neuroradiol 2:539–543, 1981
36. Gabrielsen TO, Seeger JF, Knake JE, Stilwill EW: Radiology of cerebral vein occlusion without dural sinus occlusion. Radiology 140:403–408, 1981
37. Garcin R, Pestel M: Thrombophlébites cérébrales. Paris, Masson et Cie, 1949
38. Gates PC: Cerebral venous thrombosis: A retrospective review. Aust NZ J Med 16:766–770, 1986
39. Girard DE, Reuler JB, Mayer BS, et al: Cerebral venous sinus thrombosis due to indwelling transvenous pacemaker catheter. Arch Neurol 37:113, 1980
40. Go RT, Chiu CL, Neuman LA: Diagnosis of superior sagittal sinus thrombosis by dynamic and sequential brain scanning. Report of one case. Neurology 23:1199–1204, 1973
41. Goldberg AL, Rosenbaum AE, Wang H, et al: Computed tomography of dural sinus thrombosis. J Comput Assist Tomogr 10:16–20, 1986
42. Guidetti B, Giuffre B, Gambacorta D: Follow up study of 100 cases of pseudotumor cerebri. Acta Neurochir 18:259–267, 1968
43. Hacker H: Normal supratentorial veins and dural sinuses. *In* Newton TH, Potts DG: Radiology of the Skull and Brain. Angiography. St. Louis, CV Mosby, 1974
44. Halpern JP, Morris JGL, Driscoll GL: Anticoagulants and cerebral venous thrombosis. Aust NZ J Med 14:643–648, 1984
45. Hanigan WC, Rossi LJ, Mc Lean JM, Wright RM: MRI of cerebral vein thrombosis in infancy. A case report. Neurology 36:1354–1356, 1986
46. Hanley DF, Feldman E, Borel CO, et al: Treatment of sagittal sinus thrombosis associated with cerebral hemorrhage and intracranial hypertension. Stroke 19:903–909, 1988
47. Houser OW, Campbell JK, Campbell RJ, Sundt TM: Arteriovenous malformation affecting the transverse dural venous sinus. An acquired lesion. Mayo Clin Proc 54:651–661, 1979
48. Huang YP, Wolf B: Veins of the white matter of the cerebral hemispheres (the medullary veins). Diagnostic importance in carotid angiography. AJR 92:739–755, 1964
49. Huang YP, Wolf BS: Veins of posterior fossa—superior or galenic draining group. AJR 95:808–821, 1965
50. Huang YP, Wolf BS, Antin SP, Okudera T: The veins of the posterior fossa—anterior or petrosal draining group. AJR 104:36–56, 1968
51. Hughes JP, Stovin PG: Segmental pulmonary artery aneurysms with peripheral venous thrombosis. Br J Dis Chest 53:19–27, 1959
52. Jacquin V, Salama J, Leroux G, Delaporte P: Thromboses veineuses cérébrales et

des membres supérieurs associées à une thrombopénie, induites par le polysulfate de Pentosane. Ann Med Intern (Paris) 139:194–197, 1988
53. Johnsen S, Greenwood R, Fischman MA: Internal cerebral vein thrombosis. Arch Neurol 28:205–207, 1973
54. Kalbag RM, Woolf AL: Cerebral venous thrombosis. London, University Press, 1967
55. Kinal ME: Traumatic thrombosis of dural venous sinuses in closed head injuries. J Neurosurg 27:142–145, 1967
56. Kingsley DPE, Kendall BE, Moseley LF: Superior sagittal sinus thrombosis, an evaluation of the changes demonstrated on computed tomography. J Neurol Neurosurg Psychiatry 41:1065–1068, 1978
57. Krayenbuhl H: Cerebral venous and sinus thrombosis. Clin Neurosurg 14:1–24, 1967
58. Krayenbuhl H: Cerebral venous thrombosis. The diagnostic value of cerebral angiography. Schweiz Arch Neurol Neurochir Psychiatry 74:261–287, 1954
59. Levine SR, Twyman RE, Gilman S: The role of anticoagulation in cavernous sinus thrombosis. Neurology 38:517–521, 1988
60. Levine SR, Kieran S, Puzio K, et al: Cerebral venous thrombosis with lupus anticoagulants. Report of 2 cases. Stroke 18:801–804, 1987
61. Macchi PJ, Grossman RI, Gomori JM, et al: High field MR imaging of cerebral venous thrombosis. J Comput Assist Tomogr 10:10–15, 1986
62. Martin JP, Sheenan HL: Primary thrombosis of cerebral veins (following childbirth). Br Med J 1:349–353, 1941
63. Mas JL, Meder JF, Meary E, Bousser MG: MRI imaging in lateral sinus hypoplasia and thrombosis. Stroke 21:1350–1356, 1990
64. McMurdo SK, Brant-Zawadzki M, Bradley WG, et al: Dural sinus thrombosis study using intermediate field strength MR imaging. Radiology 161:83–86, 1986
65. Meininger V, James JM, Rio B, Zittoun R: Occlusions des sinus veineux de la dure-mère au cours des hémopathies. Rev Neurol (Paris) 141:228–233, 1985
66. Meyohas MC, Roullet E: Cerebral venous thrombosis and dual primary infection with human immuno-deficiency virus and cytomegalovirus. J Neurol Neurosurg Psychiatry 52:1010–1016, 1989
67. Mickle JP, Mc Lennan JE, Lidden CW: Cortical vein thrombosis in Wegener's granulomatosis. J Neurosurg 46:248–251, 1977
68. Montrieul B, Janny P: Contribution à l'étude angiographique des thromboses veineuses cérébrales. Neurochirurgie 8:175–188, 1962
69. Murphy MF, Clarke CRA, Brearley RL: Superior sagittal sinus thrombosis and essential thrombocythaemia. Br Med J 287:1344, 1983
70. Newman DS, Levine SR, Curtis VL, Welch KMA: Migraine-like visual phenomena associated with cerebral venous thrombosis. Headache 29:82–85, 1989
71. Noetzel H, Jerusalem F: Die Hirnvenen und sinusthrombosen. Monographien Gesamtgebiete Neurologie Psychiatrie 106:1–63, 1965
72. Osborn AG, Anderson RE, Wing SD: The false falx sign. Radiology 134:421–425, 1980
73. Patchell RA, Posner JB: Neurologic complications of carcinoid. Neurology 36:745–749, 1986
74. Poltera AA: The pathology of intracranial venous thrombosis in oral contraception. J Pathol 106:209–219, 1972
75. Rao KCVG, Knipp HC, Wagner EJ: CT findings in cerebral sinus and venous thrombosis. Radiology 140:391–398, 1981
76. Ribes MF: Des recherches faites sur la phlébite. Revue Médicale Française et Etrangère et Journal de Clinique de l'Hôtel-Dieu et de la Charité de Paris 3:5–41, 1825
77. Rousseaux P, Bernard MH, Scherpereel B, Guyot JF: Thrombose des sinus veineux intra-crâniens (à propos de 22 cas). Neurochirurgie 24:197–203, 1978
78. Rousseaux M, Lesoin F, Barbaste P, Jomin M: Infarctus cérébelleux pseudotumoral d'origine veineuse. Rev Neurol (Paris) 144:209–211, 1987
79. Sauron B, Chiras J, Chain G, Castaigne P: Thrombophlébite cérébelleuse chez un

homme porteur d'un déficit familial en antithrombine III. Revue Neurol (Paris) 138:685, 1982
80. Savino PJ, Grossman RI, Schatz NJ, et al: High field magnetic resonance imaging in the diagnosis of cavernous sinus thrombosis. Arch Neurol 43:1081–1082, 1986
81. Scott JA, Pascuzzi RM, Hall PV, Becker GJ: Treatment of dural sinus thrombosis with local urokinase infusion. J Neurosurg 68:284–287, 1988
82. Scotti LN, Goldman RL, Hardman DR, Heinz ER: Venous thrombosis in infants and children. Radiology 1121:393–399, 1974
83. Sekhar LN, Dujovny M, Rao GR: Carotid cavernous sinus thrombosis caused by *Aspergillus fumigatus*. J Neurosurg 52:120–125, 1980
84. Shinohara Y, Yosmitoshi M, Yoshii F: Appearance and disappearance of empty delta sign in superior sagittal sinus thrombosis. Stroke 17:1282–1284, 1986
85. Shiozawa Z, Yamada H, Mabuchi C, et al: Superior sagittal sinus thrombosis associated with androgen therapy for hypoplastic anaemia. Ann Neurol 12:578–580, 1982
86. Sigsbee B, Deck MDF, Posner JB: Non metastatic superior sagittal sinus thrombosis complicating systemic cancer. Neurology 29:139–146, 1979
87. Sindou M, Mercier P, Brunon J, et al: Hypertension intra-crânienne "bénigne" par thrombose des deux sinus latéraux traitée par pontage veineux. Nouv Presse Med 9:439–442, 1980
88. Smith WDF, Sinar J, Carey M: Sagittal sinus thrombosis and occult malignancy. J Neurol Neurosurg Psychiatry 46:187–188, 1983
89. Snyder TC, Sachdev HS: MR imaging of cerebral dural sinus thrombosis. J Comput Assist Tomogr 10:889–890, 1986
90. Souter RG, Mitchell A: Spreading venous cortical thrombosis due to infusion of hyperosmolar solution into the internal jugular vein. Br Med J 285:935–936, 1982
91. Southwick FS, Richardson EP Jr, Swartz MN: Septic thrombosis of the dural venous sinuses. Medicine 65:82–106, 1986
92. Stansfield FR: Puerperal cerebral thrombophlebitis treated by heparin. Br Med J 1:436–438, 1942
93. Symonds CP: Hydrocephalic and focal cerebral symptoms in relation to thrombophlebitis of the dural sinuses and cerebral veins. Brain 60:531–550, 1937
94. Sze G, Simmons B, Krol G, et al: Dural sinus thrombosis: Verification with spin echo techniques. AJNR 9:679–686, 1988
95. Tarras S, Gadia C, Mester L, et al: Homozygous protein C deficiency in a newborn. Clinicopathologic correlation. Arch Neurol 45:214–220, 1988
96. Tehindrazanarivelo A, Evrard S, Schaison M, et al: Prospective study of cerebral sinus venous thrombosis in patients presenting with benign intra-cranial hypertension. Submited to Cerebrovascular Disease
97. Thron A, Wessel K, Linden D, et al: Superior sagittal sinus thrombosis: Neuroradiological evaluation and clinical findings. J Neurol 233:283–288, 1986
98. Towbin A: The syndrome of latent cerebral venous thrombosis: Its frequency and relation to age and congestive heart failure. Stroke 4:419–430, 1973
99. Van Vleymen B, de Haenne I, van Hoof A, Pattyn G: Cerebral venous thrombosis in paroxysmal nocturnal haemoglobinuria. Acta Neurol Belg 87:80–87, 1987
100. Vidailhet M, Piette JC, Wechsler B, et al: Cerebral venous thrombosis in systemic lupus erythematosus. Report of 6 cases and review. Accepted for publication in Stroke
101. Villringer A, Garner C, Meister W, et al: High dose heparin treatment in cerebral sinus venous thrombosis. Stroke 19:135, 1988
102. Villringer A, Seiderer M, Bauer WM, et al: Diagnosis of superior sagittal sinus thrombosis by three-dimensional magnetic resonance flow imaging. Lancet 1:1086–1087, 1989
103. Vines FS, Davis DO: Clinical radiological correlation in cerebral venous occlusive disease. Radiology 98:9–22, 1971
104. Virapongse C, Cazenave C, Quisling R, et al: The empty delta sign: Frequency

and significance in 76 cases of dural sinus thrombosis. Radiology 162:779–785, 1987
105. Yasargil MG, Damur M: Thrombosis of the cerebral veins and dural sinuses. *In* Newton TH, Potts DG: Radiology of the Skull and Brain. Angiography. St. Louis, CV Mosby, 1974
106. Yerby MS, Bailey GM: Superior sagittal sinus thrombosis 10 years after surgery for ulcerative colitis. Stroke 11:294–295, 1980

Address reprint requests to

Marie-Germaine Bousser, MD
Service de Neurologie
Hôpital Saint-Antoine
184, rue du Faubourg Saint-Antoine
Paris 75571
France