Cerebral venous sinus thrombosis is relatively uncommon, with mortality rates ranging from 5 to 30%. It is associated with hypercoagulable states secondary to dehydration, meningitis, pregnancy, sickle cell disease, oral contraceptive use, and numerous other conditions. Diagnosis may be difficult because of nonspecific signs and symptoms. This difficulty may lead to a significant delay in diagnosis, which directly affects prognosis.

Diagnosis is made based on a high index of suspicion and neuroimaging results. Cerebral venous thrombosis may be recognized because of a venous infarction or a hemorrhage in an atypical location on CT or MR imaging. Additionally, thrombosis may be seen as a hyperdense area in a dural venous sinus on unenhanced CT scans or as a void in the sinus on enhanced CT scans (this has been referred to as the empty delta sign). Although conventional angiography remains the gold standard for diagnosis, cerebral venous thrombosis may be clearly and accurately visualized using MR imaging and MR venography.

The potential for neurological recovery is dependent on early treatment delivered prior to the onset of venous infarction and/or hemorrhage. The optimal treatment is controversial, in part because of the variable nature of the disease process. Systemic anticoagulation therapy is often the first-line treatment. Heparin has been shown to lead to improved outcome following venous sinus thrombosis compared with no treatment. Anticoagulant agents such as heparin only limit propagation of the thrombosis and therefore do not lyse the existing thrombus. Clot propagation and clinical progression may be halted, but if occlusion of the sinus is not tolerated (that is, there is insufficient collateralization), restoration of venous sinus patency is required.

Reports on the use of peripheral and direct delivery of thrombolytic agents have been published. Intravenous delivery has resulted in various outcomes and a significant amount of time is required for thrombolysis (that is, days). Direct endovascular delivery of thrombolytic drugs to the site of thrombosis has yielded favorable results. Despite these promising findings, the use of thrombolytic agents is still associated with an increased incidence of hemorrhage and significant time is required for recanalization.

Mechanical thrombectomy with the rheolytic catheter (AngioJet Xpeedior 100; Possis Medical, Minneapolis, MN) is an exciting option for dural sinus thrombosis (Fig. 1). This device has been used successfully in the treatment...
Transcranial approach for direct thrombectomy of cerebral venous thrombosis, for which we used a transcranial approach.

**Case Reports**

**Case 1**

*History and Examination.* This 48-year-old man was transferred to our institution after experiencing a 3-month progressive deterioration in neurological function. The patient presented with somnolence, bilateral tremor, and diffuse hyperreflexia. Admission MR images of the brain demonstrated a hyperintense signal in the bilateral thalami and basal ganglia and angiography revealed occlusion of the proximal straight sinus (Fig. 2). All laboratory values were within normal limits and no known associated comorbidities were identified.

*Initial Treatment.* Despite heparin infusion, the patient’s neurological status continued to decline. The rapidity of the decline precluded intravenous thrombolytic therapy. The patient was considered for mechanical thrombectomy but the deep nature of the thrombosis (that is, in the straight sinus) precluded an approach through the transfemoral or jugular route. This is because the stiff catheter cannot be easily navigated around the bend from the torcular herophili to the straight sinus.

*Operation.* The patient was brought to the operating room, placed in a three-quarters prone position, and a three-point headholder was affixed. An approximately 2-cm craniotomy was performed directly over the torcular herophili, which was directly pierced using a micropuncture kit (Fig. 3). The AngioJet Xpeedior 100 catheter was advanced over a wire past the thrombosis. Mechanical thrombectomy was performed twice and venography demonstrated anterograde flow into the straight sinus (Fig. 4). The puncture in the sinus was secured with thrombin-soaked Gelfoam and the bone flap was replaced.

*Postoperative Course.* The patient was maintained on heparin infusion and eventually started on a regimen of coumadin and baby aspirin. His neurological status improved daily until he was discharged to a rehabilitation facility. At the last scheduled follow-up visit, the patient’s level of consciousness and right-extremity paresis had improved. Results of the hyperreflexia and cranial nerve palsy and third cranial nerve palsy were normal.

**Case 2**

*History and Examination.* This 58-year-old man had a family history of protein S deficiency and was transferred to our institution with a 3-month history of new-onset left hemiparesis and third cranial nerve palsy. Diagnostic angio-MR revealed a left frontal and middle third of the SSS. The SSS was directly pierced using a micropuncture kit (Fig. 3). The AngioJet Xpeedior 100 catheter was advanced over a wire past the thrombosis. Mechanical thrombectomy was attempted through a transfemoral and transjugular route, but it was unsuccessful because of anatomical constraints and difficulty navigating around the bend from the torcular herophili to the straight sinus.

*Operation.* Therefore, the patient was brought to the operating room for direct transcranial mechanical thrombectomy. A family history of protein S deficiency was transferred to our institution with a right-sided temporoparietal hemorrhage. The patient’s neurological status continued to decline and he experienced a generalized tonic–clonic seizure along with new right-extremity paresis. A CT scan revealed a left-sided frontotemporal hemorrhage. Catheter angiography demonstrated a dural arteriovenous fistula, which was successfully embolized. Subsequently, diagnostic angiography revealed occlusion of the proximal straight sinus (Fig. 2). All laboratory values were within normal limits and no known associated comorbidities were identified.

*Initial Treatment.* Despite heparin infusion, the patient’s neurological status continued to decline. The rapidity of the decline precluded intravenous thrombolytic therapy. The patient was considered for mechanical thrombectomy but the deep nature of the thrombosis (that is, in the straight sinus) precluded an approach through the transfemoral or jugular route. This is because the stiff catheter cannot be easily navigated around the bend from the torcular herophili to the straight sinus.

*Operation.* The patient was brought to the operating room, placed in a three-quarters prone position, and a three-point headholder was affixed. An approximately 2-cm craniotomy was performed directly over the torcular herophili, which was directly pierced using a micropuncture kit (Fig. 3). The AngioJet Xpeedior 100 catheter was advanced over a wire past the thrombosis. Mechanical thrombectomy was performed twice and venography demonstrated anterograde flow into the straight sinus (Fig. 4). The puncture in the sinus was secured with thrombin-soaked Gelfoam and the bone flap was replaced.

*Postoperative Course.* The patient was maintained on heparin infusion and eventually started on a regimen of coumadin and baby aspirin. His neurological status improved daily until he was discharged to a rehabilitation facility. At the last scheduled follow-up visit, the patient’s level of consciousness and right-extremity paresis had improved. Results of the hyperreflexia and cranial nerve palsy were normal.

**Figure 1.** A: Depiction of the Angiojet. B: Depiction of the catheter in the thrombus. This mechanical device forces a very high-speed jet of saline down the body of the instrument. At the end of the device the saline makes a 180˚ U-turn and is exposed over a very short distance. This high-speed saline jet creates a suction or a vacuum effect, and any material nearby will be entrained in the moving saline stream and evacuated out through the catheter. Arrows show the direction of the jets of saline. Pictures courtesy of Possis Medical.

**Figure 2.** Diagnostic conventional angiogram in the venous phase demonstrating straight sinus occlusion.

**Figure 3.** Intraoperative photograph obtained after midline incision over the inion showing a small craniotomy turned over the torcular herophili. The torcular herophili was directly punctured and No. 6 French sheath was placed.
Transcranial approach for direct thrombectomy of sinus thrombosis

Fig. 4. Postoperative angiogram demonstrating that after mechanical thrombolysis, flow was restored through the straight sinus.

Fig. 5. Lateral catheter angiogram (venous phase) demonstrating complete occlusion of the SSS.

Discussion

Cerebrovascular sinus thrombosis is a rare condition with an occurrence of 1.5 to 3 per million in adults and approximately 7 per million in children (Canadian Pediatric Ischemic Stroke Registry). It usually affects young people who are otherwise healthy and often presents with nonspecific signs and symptoms. The clinical diagnosis requires a high index of suspicion because there are no pathognomonic findings. Patients may present with headaches, nausea and/or vomiting, a depressed level of consciousness, seizures, and/or focal neurological deficits.1,4,6,7,8,12

Thrombolysis, chemical thrombolysis, or mechanical thrombectomy was attempted through a transfemoral and transjugular route, but it was unsuccessful because of anatomical constraints and difficulty navigating the catheter. Therefore, the patient was brought to the operating room for direct transcranial mechanical thrombectomy. A craniotomy was planned and performed over the junction of the frontal and middle third of the SSS. The SSS was directly pierced using a micropuncture kit and a No. 6 French sheath pierced over the torcular herophili, which was advanced over the torcular herophili, and a piece of pericranium, and the bone flap was replaced with miniplates.

Postoperative Course. The patient was begun on a regimen of heparin infusion that was eventually converted to coumadin. He slowly improved neurologically following the thrombectomy, and at the latest follow-up review he was living independently and had a normal mental status, baseline left hemiparesis, and new mild right upper-extremity weakness (Grade 4/5). Subsequent hematological evaluation disclosed protein S deficiency.

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a whole; four of five patients suffered hemorrhagic complications and only two of five exhibited clinical improvement. Systemic anticoagulation therapy with heparin is commonly used and in many instances it is effective in preventing thrombus propagation and results in improved neurological status. Einhaupl, et al. demonstrated improved outcome in patients who received heparin compared with those who did not. It has been and still is common practice among many neurosurgeons and neurologists to avoid anticoagulation therapy in the setting of venous thrombosis and ICH for fear of exacerbating the bleeding. Despite this belief, it has been shown that systemic anticoagulation with heparin is both safe and effective for the treatment of venous sinus thrombosis, even in the face of a preexisting ICH.1,2,3 Systemic thrombolysis with urokinase has had some occasionally good yet inconsistent results.2,3,12 Many positive reports on the use of direct endovascular delivery of thrombolytic agents exist in the literature.2,3,17–22,24,27,35,38,40,41 It appears that thrombolytic drugs are effective at improving flow through the occluded sinus and improving patient outcome.28

Despite reported success with systemic and especially direct thrombolytic therapy, a potentially long time is required to achieve effective recanalization. This leads to a substantial risk of hemorrhagic complications (30% of patients who receive either tissue plasminogen activator or urokinase, according to a report by Soleau, et al.29) Despite this risk of hemorrhage, 90% of sinus patency was restored and 60% of patients demonstrated clinical improvement. A significant amount of time is required to restore patency with chemical thrombolysis; studies have demonstrated infusion times of 88 to 244 hours, with a mean of 171 hours for lysis of massive clots.30,31

Mechanical thrombectomy obviates the time required and averts potential hemorrhagic complications seen with chemical thrombolysis. Options include the use of endovascular Fogarty catheters and the Angiojet rheolytic thrombectomy catheter. With the latter, saline exits the catheter tip at high velocity through small jets oriented in a retrograde direction. These jets create a negative pressure gradient at the tip of the catheter; this is known as the Venetian effect. This negative pressure gradient serves to entrap and gent- ly break up the thrombus.32 The catheter has been success- fully used to treat thrombosis of the coronary, pulmonary, and other peripheral vessels.33,34,35 Furthermore, successful thrombolysis of dural venous sinuses has recently been reported.35,36

Although mechanical thrombectomy may be optimal for the management of cerebral venous thrombosis, it cannot be applied in every patient. The catheter is relatively stiff, making navigation through tortuous or thrombosed vessels difficult and at times impossible. Furthermore, navigation into the deep venous structures (for example, straight sinus and beyond) may not be possible. These limitations may be especially true for a transfemoral approach. For these reasons, some practitioners have used a jugular approach for the application of the Angiojet system. If one is unable to navigate the thrombus from this access point, the procedure may need to be abandoned.

A transcranial approach has been used by Houdart, et al.37 for embolization of dural arteriovenous fistula; these authors described their successful approach in 10 patients. In all patients in their series, a cranietomy was used to per-
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In patients with venous thrombosis, the frontal and lateral sinus thrombosis in neonates and children. Pediatr Neurol 8:112–116, 1992

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