Published in final edited form as:

J Child Neurol. 2012 March ; 27(3): 337–345. doi:10.1177/0883073811421827.

Prolonged Direct Catheter Thrombolysis of Cerebral Venous Sinus Thrombosis in Children: A Case Series

Jeff Waugh, MD, PhD¹, Patricia Plumb, RN, MSN²,ancy Rollins, MD⁴, and Michael M. Dowling, MD, PhD, MSCS^{2,3}

¹Department of Neurology, Children's Hospital Boston, Boston, MA, USA

²Department of Pediatrics, University of Texas Southwestern Medical Center, Dallas, TX, USA

³Department of Neurology, University of Texas Southwestern Medical Center, Dallas, TX, USA

⁴Department of Radiology, University of Texas Southwestern Medical Center, Dallas, TX, USA

Abstract

Cerebral venous sinus thrombosis is a rare condition with potentially devastating neurologic outcome—death and severe disability are common in advanced cases. In adults, protocols for mechanical clot disruption and direct thrombolysis are established; no guidance exists for children. We present our experience of 6 children with cerebral venous sinus thrombosis and ominous clinical progression. We found that effective thrombolysis required substantially longer infusion, more rounds of mechanical disruption, and higher doses of thrombolytics than are commonly practiced. Despite pervasive thrombosis, prethrombolysis hemorrhage, coma, and other predictors of death and disability, our patients survived and 4 of 6 had no functional deficits. One patient had moderate, and one had severe deficits. We report these cases to illustrate that hemorrhage may not be a contra-indication to thrombolysis for cerebral venous sinus thrombosis, that prolonged infusion may be required to restore perfusion, and that good neurologic outcomes can be achieved despite dire clinical presentations and extensive sinus thrombosis.

Keywords

cerebral venous sinus thrombosis; catheter-guided direct thrombolysis; dural sinus thrombosis

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Corresponding Author: Michael M. Dowling, MD, PhD, MSCS, 1935 Motor Street, Dallas, TX 75235, Michael.Dowling@utsouthwestern.edu.

Author Contributions

JW collected retrospective data and prepared the images and the table and was the primary author of the manuscript. PP conducted RRQ interviews and edited the manuscript. NR performed all reported thrombolysis, assisted in image preparation, and edited the manuscript. MMD was responsible for article conception and edited the manuscript.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

We certify that all authors and clinical associates comported themselves in an ethical and professional manner in all dealings with the patients in question. This study was conducted with the approval of the University of Texas Southwestern Medical Center Institutional Review Board.

Background

Cerebral venous sinus thrombosis is uncommon in children, with an incidence of 0.67 out of 100 000 per year,¹ but in severe cases can progress to venous infarction or hemorrhage. Outside of the neonatal period, sinus thrombosis is associated with an 8% mortality² and up to 50% of survivors suffer neurologic deficits.^{1,2} Consensus treatment guidelines for childhood cerebral venous sinus thrombosis recommend conservative supportive and symptomatic measures including adequate hydration, treatment of underlying conditions, addition of antibiotics for children with suspected bacterial infection and control of seizures or elevated intracranial pressure. Although there have been no randomized, placebo-controlled trials in children, extrapolation from limited adult trials led to recommendations for anticoagulation with unfractionated heparin or low molecular weight heparin in children with sinus thrombosis outside the neonatal period, even in the presence of secondary hemorrhage.^{3–5}

Direct thrombolytic therapy has been used in both adults and children with severe cerebral venous sinus thrombosis. Multiple individual case reports and small series suggest that thrombolytic therapy may successfully treat seriously ill children and adults, including comatose patients with extensive thrombosis of superficial and deep cerebral veins.^{6–11} However, a Cochrane review in 2004¹² identified no randomized controlled clinical trials of thrombolysis in children or adults; our searches of the literature since 2004 have likewise yielded no such trials.

Based on these relatively scant data, the guidelines recommend that thrombolysis be considered “only in children with severe CVST [cerebral venous sinus thrombosis], for whom there is no improvement with initial unfractionated heparin therapy,”³ or that thrombolysis “may only be considered in carefully selected patients with progressive neurological deterioration despite intensive and therapeutic levels of anticoagulant treatment.”⁵ There are no clear treatment protocols for such thrombolytic therapy in children and there are limited data on the actual doses and duration of therapy used in the reported pediatric cases of successful cerebral sinus thrombolysis. We present our institutional experience and general protocol for prolonged direct catheter thrombolysis of cerebral venous sinus thrombosis in children.

Methods

With approval of the University of Texas Southwestern Medical Center Institutional Review Board, we queried hospital databases and identified 6 cases of children with cerebral venous sinus thrombosis who had undergone direct thrombolysis at our institution from 2000 to 2010. Medical records and imaging studies were reviewed retrospectively. We collected data on clinical presentation, predisposing conditions, indications for thrombolysis, imaging findings, tissue plasminogen activator dose and duration of therapy, and clinical outcomes. This was a single-institution series and so may not adequately represent patients at other institutions.

Computed tomography (CT), magnetic resonance imaging (MRI) with MR venography, and epidural venography done during thrombolytic therapy were reviewed and assessed using the Rabinstein score,¹³ a cerebral sinus thrombosis scoring system designed to quantify the distribution of the clot. This scale assigns 1 point for each involved sinus, internal cerebral vein, the vein of Galen, and for each third of the superior sagittal sinus¹³; the maximum score is 10. Scores of 3 or higher correlate with an increased risk of venous infarct or parenchymal hemorrhage in cerebral venous sinus thrombosis, though the extent of thrombosis and severity of brain lesion may not correlate in any individual patient. Note that the Rabinstein score has not been evaluated for use in children. Note also that the purpose of this report is not to evaluate the utility of the Rabinstein score in children but rather to reflect our clinical impression—that these patients had widespread cerebral sinus thrombosis—in an objective, numerical manner.

Clinical outcomes were assessed by the Recovery Recurrence Questionnaire form of the Pediatric Stroke Outcome Measure^{14,15} which quantifies neurologic outcomes and is validated in children with stroke. Deficits were scored as none (zero), mild with no impact on function (score = 0.5), moderate (1), or severe (2) in each of 5 domains, including sensory or motor deficits on the right and left, language deficits, both receptive and productive, and cognitive/behavioral deficits, with a maximum score of 10.

Case Reports

Case 1—This 17-year-old previously healthy boy presented with vomiting, severe frontal headache with photophobia, and right hemiparesis after suffering dehydration from a diarrheal illness. He had a focal seizure affecting the right arm and leg and rapidly progressed to decerebrate posturing. MR venography demonstrated thrombosis of the superior sagittal sinus, straight sinus, vein of Galen, right internal cerebral vein, and bilateral transverse sinuses. A right frontal Camino bolt was placed at an outside hospital (Figure 1A). Risk factors for thrombosis included dehydration, antiphospholipid antibodies, and homozygous prothrombin gene mutation.

On admission, retrograde epidural venography was performed that confirmed the MR venography findings. The clot within the superior sagittal sinus was macerated with a wire and laced with 10 mg tissue plasminogen activator. The tissue plasminogen activator was infused continuously for 24 hours. At 14 hours and again at 22 hours, epidural venography was repeated along with clot maceration and repositioning of the microcatheter into the residual clot (Figure 1C). There were 3 total cycles of maceration and repositioning. A small parenchymal hematoma formed around the bolt, though no intervention was required (Figure 1B). The patient recovered without motor deficits and is seizure free on a single medication. At early follow-up, he suffered from mild higher level cognitive deficits but was able to attend college.

Case 2—This 15-year-old boy with ectodermal dysplasia presented with 2 weeks of intermittent headache and 1 week of fatigue and lethargy. He then had an acute loss of consciousness of 2 minutes' duration distinct from any recognized seizure activity followed by right-sided weakness and strabismus. MR venography demonstrated thrombosis of the

superior sagittal sinus, left transverse and sigmoid sinuses, the left internal jugular vein, and partial occlusion of the straight sinus and internal cerebral veins. A left occipital subdural hemorrhage was noted on CT. His only identified risk factor for thrombosis was heterozygosity for factor V Leiden.

He was managed with intravenous fluids and aspirin (81 mg daily) but had progressive deterioration in mental status and was transferred to our facility on hospital day 5. Direct thrombolysis included 4 total rounds of clot maceration and bolus administration of tissue plasminogen activator every 12 to 24 hours. Continuous infusion of tissue plasminogen activator lasted 79 hours; in total 61 mg of tissue plasminogen activator was given. His mental status progressively improved with resolution of his right-sided weakness. The tissue plasminogen activator infusion was stopped with the onset of right-sided weakness and dysarthria; CT showed new hemorrhage into the external capsule. The superior sagittal sinus rethrombosed without further clinical progression. Long-term follow-up showed persistent mild right hemiparesis without cognitive deficits, and he is now preparing to attend college.

Case 3—This 9-year-old boy with high-risk pre-B cell acute lymphocytic leukemia was on day 17 of induction chemotherapy (including vincristine and polyethylene glycol-asparaginase) when he suffered a focal motor seizure affecting the right arm and leg. MRI demonstrated an occlusive thrombus involving the middle third of the superior sagittal sinus and bilateral cortical veins, complicated by large venous infarct, cortical and subcortical edema in the left frontal and parietal lobes, a small subarachnoid hemorrhage in the left parietal lobe, and a small hemorrhage in the left parietal white matter. His hypercoagulable evaluation was negative. His identified risk factors for thrombosis were leukemia and chemotherapy with asparaginase.

Because of worsening mental status, direct thrombolysis and clot maceration were performed twice with 21 hours of continuous tissue plasminogen activator infusion. He received a total of 14 mg of tissue plasminogen activator. Resolution of the sinus thrombosis was associated with normalization of clinical status. However, the clot recurred several days later with an increase in the size of the venous infarct and hemorrhage, which precluded further thrombolysis. Over the short term, the patient had problems with attention and fine motor tasks and required subsequent cognitive therapy. One month after diagnosis of his cerebral venous sinus thrombosis, he suffered a left middle cerebral artery embolic infarct, resulting in aphasia and right-sided weakness. The patient died 5 months later due to complications of leukemia.

Case 4—This 12-year-old boy was in delayed intensification chemotherapy for high-risk pre-B cell acute lymphocytic leukemia. Polyethylene glycol (PEG)-asparaginase had been given 1 month earlier and doxorubicin and vincristine 3 days earlier to the onset of progressive right leg weakness and a moderate, throbbing, left-sided headache. Slowed speech, anomia, and vomiting prompted his admission. The patient had a slowed, but not ataxic, gait and diffuse right-sided deficits: lower facial droop, diminished strength in upper and lower extremities, loss of the patellar reflex, and stocking hyperesthesia. MR venography showed occlusion of the anterior two-thirds of superior sagittal sinus, both transverse sinuses, and the left jugular vein along with multiple left cortical veins. There was

pervasive venous infarction of the subcortical white matter and a small hemorrhage in the left superior frontoparietal lobe, which extended prior to tissue plasminogen activator lysis. Hypercoagulable evaluation was negative and he had no clinical signs of infection or dehydration. His only known risk factors were the use of PEG-asparaginase, leukemia, and dehydration.

He underwent a single round of thrombolysis and maceration with complete resolution of thrombus over 16 hours and a total tissue plasminogen activator dose of 11 mg. His only remaining symptom is a right foot drop, possibly due to vincristine. He is doing well in regular classes.

Case 5—This 10-year-old boy with trisomy 21 and a protein-losing enteropathy presented after 1 week of diarrheal illness with decreased fluid intake, generalized weakness, and depressed affect. On the day of admission, he developed bilateral leg weakness and ataxia. MR venogram and conventional venography demonstrated occlusion of the left sigmoid and transverse sinus, the torcula, and partial thrombosis of the proximal straight and superior sagittal sinuses (Figure 2A). There were nonhemorrhagic infarcts of both the parietal lobes and the white matter of the left cerebellum. He was initially managed with intravenous fluids and heparin, but progressive weakness following admission and the development of generalized tonic clonic seizures led to intensification of therapy.

As the earliest case in this series, this patient was initially treated with catheter-directed pro-urokinase, followed by 5 rounds of tissue plasminogen activator lysis, delivering a total of 60 mg of tissue plasminogen activator. His intracranial catheter remained in place for 102 hours. He had no hemorrhagic complications. Over the 4 days of direct lysis, his thrombosis progressively resolved and was absent on follow-up imaging (Figure 2B). His mentation and focal neurologic deficits progressively improved, but lower extremity dysmetria and weakness persisted at the time of discharge. These deficits resolved completely and 10 years later, he is a senior in high school in a special education program. His only identifiable cognitive deficits are on par with his baseline status from trisomy 21.

Case 6—This 12-year-old boy presented to an outside hospital with headache and decreased vision that had been worsening over 4 weeks. He had been blind in his left eye for 2 weeks, with worsening acuity in his right eye for 1 week. He developed nausea and vomiting, and had a sixth cranial nerve palsy and papilledema on examination. MRI demonstrated a 4 × 4 cm temporal lobe tumor as well as complete occlusion of the superior sagittal sinus, bilateral transverse sinuses, and thrombosis of the left parietal cortical veins. In addition to his primary tumor (later found to be a pilocytic astrocytoma), predisposing factors included factor V Leiden mutation and antiphospholipid antibodies, which were thought to be paraneoplastic.

The extent of his thrombosis and the evident risk to his vision from increased intracranial pressure prompted a rapid attempt at direct thrombolysis with resulting improvement in venous outflow. In total, he received 36 mg of tissue plasminogen activator delivered into the superior sagittal sinus or torcula during 3 rounds of lysis and over 54 hours of continuous infusion. While on continuous tissue plasminogen activator infusion, the patient developed a

severe headache and was noted to have rapidly deteriorating neurologic status. CT showed small intraparenchymal and subdural hemorrhages and enlarged ventricles. He required mannitol, hypertonic saline, emergent ventriculostomy, and pentobarbital coma for management of increased intracranial pressure. The superior sagittal sinus and transverse sinuses rethrombosed with cessation of tissue plasminogen activator and heparin infusions and progressed to include the straight sinus and bilateral sigmoid sinuses. Over subsequent weeks, he developed multifocal bilateral infarctions and hemorrhages, leaving him with hemiparesis in addition to the blindness present on admission. After stabilization, he underwent tumor resection. He subsequently had radiographic progression of his tumor and underwent a second resection. He has had stable residual tumor noted on subsequent imaging studies. He is in special education classes in a regular school, can walk with assistance, and can read Braille.

Results and Discussion

We identified 6 pediatric patients who presented with cerebral venous sinus thrombosis and who underwent catheter-directed thrombolysis at variable times following symptom onset, from 48 hours to 4 weeks (Table 1). The large variability in times from symptom onset to treatment with direct thrombolysis was due to the differing speed of progression from mild initial symptoms to deteriorating mental status; all patients were correctly diagnosed on presentation. Four were diagnosed at other facilities and were transferred to our institution.

Clinical Presentations and Predisposing Conditions

These children were severely affected and the decision to proceed with thrombolytic treatment was made on the basis of the severity of their illness and their clinical progression. Coma and seizures are recognized predictors of mortality in children with cerebral sinus thrombosis.² In our patients, 5 of the 6 were comatose at the time of treatment, and 2 presented with seizures, while a third developed seizures as his condition worsened. Predictors of poor outcome in adults with cerebral venous sinus thrombosis include older age, male sex, depressed level of consciousness, central nervous system infection, cancer, thrombosis of the deep cerebral venous system, and hemorrhage on admission imaging.¹⁶ In our patient group, 3 had malignancy and 3 had thrombosis that included the internal cerebral veins. In 3 of the 6, intracranial bleeding was present (subdural, subarachnoid, or intraparenchymal) before the intervention. Notably, all patients in this series were male.

Predisposing conditions in our patients included malignancy: pre-B cell acute lymphoblastic lymphoma treated with PEG-asparaginase in 2 cases, a newly diagnosed pilocytic astrocytoma in another. Systematic testing for hypercoagulable states was not performed, but clinical testing identified hypercoagulable genotypes in 3, and antiphospholipid antibodies were detected in 2. One patient had a protein-losing enteropathy, a hypercoagulable state. Three had dehydration at presentation. Central nervous system infections were not identified in our patients.

Imaging Findings

Venous infarction (hemorrhagic or nonhemorrhagic) and severe degrees of sinus thrombosis are associated with poor outcomes in children with cerebral venous sinus thrombosis.¹ Three of 6 patients had evidence of venous infarction on MR imaging. Another marker of severity is the extent of thrombosis; our patients had severe disease by this standard as well. Rabinstein severity scores gauging the extent of the cerebral venous sinus thrombosis ranged from 2 to 9 (mean 6.3; Table 1) from a maximum possible score of 10. Notably, the mean Rabinstein score for our series (6.3) is substantially higher than that of the “poor outcome” group reported by Zubkov *et al* (3.1) and none of the 57 adults in that series had a score as high as our mean.¹³ Indeed, by this measure only one of our patients was in a low-risk group. Paradoxically, he had extensive venous infarction.

Treatment and Outcomes

The diagnosis of cerebral venous sinus thrombosis and the delineation of the extent of thrombus are best made by contrast-enhanced CT or MRI. Monitoring the progress of direct thrombolysis is best accomplished by transfemoral retrograde epidural venography, which entails retrograde catheterization of the superior sagittal sinus using a 3-French microcatheter inserted coaxial through a guiding catheter in the internal jugular vein (Figure 1C). In the hands of an experienced operator, retrograde epidural catheter placement for thrombolytic therapy in children is relatively straightforward and uncomplicated.

Systemic intravenous anticoagulation with unfractionated heparin was, in general, begun at the time of initial diagnosis and maintained for the duration of tissue plasminogen activator infusion. The standard medical therapy for cerebral venous sinus thrombosis without significant hemorrhage is systemic heparinization, and treatment guidelines support heparinization in children with progressive thrombosis, even in the presence of significant hemorrhage.^{3,4} In adult studies of thrombolysis in cerebral venous sinus thrombosis, local tissue plasminogen activator has been used in combination with systemic heparin as the standard protocol at our⁸ and other institutions.^{17,18}

Direct mechanical disruption (clot maceration) was attempted with the catheter and tissue plasminogen activator was instilled directly into the accessible clot with the dose adjusted for the extent of thrombus: 2 to 10 mg followed by continuous intra-sinus infusion of tissue plasminogen activator at 0.5 mg/h. During continuous infusion, activated clotting time was maintained at about 200 and verified every 2 to 4 hours, and the rate of tissue plasminogen activator infusion was decreased to 0.25 mg/h for fibrinogen <150 mg/dL and stopped for fibrinogen <100 mg/dL or if serious bleeding was noted. Patients were closely monitored with repeated CT, usually at intervals of 10 to 20 hours or as clinically indicated.

Every 12 to 24 hours, the patient was transported from the intensive care unit to the interventional radiology suite for repeat contrast injection through the microcatheter and repositioning of the catheter into the residual clot, with repeated cycles of venography, mechanical disruption, instillation of tissue plasminogen activator bolus, followed by continuous infusion. In general, patients were treated until there was radiographic

improvement or they developed complications related to anticoagulation or tissue plasminogen activator infusion.

Our patients underwent 1 to 5 rounds (mean 3) of mechanical disruption/tissue plasminogen activator bolus, followed by continuous intrasinus tissue plasminogen activator infusion with a total indwelling sinus catheter time from 16 to 102 hours (mean 49.3 hours). Total tissue plasminogen activator dose ranged from 11 to 61 mg (mean 38.2 mg). This treatment improved venous outflow, with resolution or improvement of clot burden in 5 of 6. Three patients had recurrence of their cerebral venous sinus thrombosis following cessation of tissue plasminogen activator infusion (cases 2, 3, and 6). In case 2, radiographic recurrence did not lead to clinical decline, so recurrence was not retreated. We presume that just as in the large sinuses, outflow in venous collaterals was improved by thrombolysis and that this flow was sufficient to divert intracranial venous blood. In cases 3 and 6, retreatment was precluded by worsening hemorrhage. In general, clinical improvement lagged behind reduction in thrombus. There was no sinus thrombosis- or treatment-related mortality. One death, from underlying acute lymphocytic leukemia and sepsis, occurred 10 months following the thrombolysis procedure. This patient (case 3) had a good neurologic recovery from cerebral venous sinus thrombosis as assessed 2 months before his demise.

Complications of thrombolysis included hemorrhage in 5 of the 6 patients. These were largely subdural hematomas or non-distorting intraparenchymal hemorrhages. This included a small hematoma around the intracranial pressure monitor probe that did not require intervention (case 1; Figure 1B). There was one large hemorrhage that was an extension of a preexisting venous infarct. One patient (case 6) had small posterior fossa intraparenchymal and subdural hemorrhage and acute hydrocephalus prompting cessation of tissue plasminogen activator and anticoagulation.

Our hemorrhage rate was higher than that reported in a study of pediatric cerebral venous sinus thrombosis treated with anticoagulation¹⁹; however, that study included many less severely affected children and did not include the use of tissue plasminogen activator. They reported major anticoagulation-related hemorrhage in 1 of 46 (2.2%) children without intracranial hemorrhage before anticoagulation and in 2 of 15 (13.3%) children who had intracranial hemorrhage before initiation of anticoagulation. In our study, with more severely affected children at baseline, hemorrhage occurred in 3 (50%) before initiation of thrombolytic therapy, and 5 of 6 (83%) patients following thrombolysis. Only 2 of 6 (33%) had major hemorrhagic events that changed the course of therapy or were thought to contribute to outcome. A systematic review of thrombolysis in adults with cerebral venous sinus thrombosis reported major intracranial hemorrhage in 12 of 156 (7.7%) patients, with 7 deaths, in this group.²⁰ While the rate of hemorrhage was higher in our small study, none of our patients died from their cerebral venous sinus thrombosis or treatment.

Neurologic outcomes in this group of severely affected children were overall good. Recurrence and Recovery Questionnaire Parental Pediatric Stroke Outcome Measure scores ranged from 0 to 7 (out of 10) with a mean of 1.5. Three patients had scores of zero (no deficits) and their parents felt there was no residual disability related to the cerebral venous sinus thrombosis. One had a mild right hemiparesis with no impact on function (outcome

score = 0.5/10). One child with acute lymphocytic leukemia and recurrent sinus thrombosis (case 3) suffered a new arterial ischemic stroke 1 month after thrombolytic treatment. At follow-up, he had only a mild right hemiparesis and moderate cognitive-behavioral deficits (outcome score = 1.5/10).

Four of the 6 patients had no cognitive deficits on formal neurologic examination, while another was cognitively unaffected from his baseline of moderate cognitive impairment. At present 1 patient is currently in university and another is currently applying for university. One is in regular classes in seventh grade and another with trisomy 21 (case 5) is completing high school with an Individualized Education Plan. His cognition and school performance appear unaffected by his sinus thrombosis. The worst outcome was noted in a boy with pilocytic astrocytoma requiring 2 resections and extensive thrombosis complicated by hemorrhage and extension of his thrombus (case 6). He is blind, ambulates with assistance only, and has moderate receptive and expressive language deficits (outcome score = 7/10) but he is able to read Braille and is in special education classes.

Conclusions

Cerebral venous sinus thrombosis can be fatal or disabling if untreated, and even with systemic anticoagulation the condition may progress. These 6 boys with severe, extensive sinus thrombosis underwent emergent prolonged catheter-directed thrombolysis, based on the judgment of their treating physicians that their deteriorating clinical condition warranted this high-risk intervention. There were no cerebral venous sinus thrombosis or procedure-related deaths and despite the severity of disease—as assessed by their underlying etiologies, clinical presentations, imaging findings, and Rabinstein severity scores—there were good outcomes in 5 of 6 patients, even in those with hemorrhage prior to thrombolysis.

We report these patients to highlight that successful treatment of severe cerebral venous thrombosis by thrombolysis is possible, even in the presence of small hemorrhage. In the design of future controlled clinical trials in children with severe sinus thrombosis,¹² bleeding may not be an absolute contraindication to thrombolytic treatment. Further, few studies have reported on the duration of thrombolytic therapy. Our patient experience suggests that prolonged and continuous infusion of thrombolytic agents, usually in excess of 24 hours' and up to 100 hours' duration, may be necessary to resolve intrasinus thrombus. Moreover, we speculate that prior efforts at thrombolysis using inadequate doses or insufficient duration of therapy may have led to treatment failure; such cases would likely go unreported because of negative publication bias. In our experience, prolonged treatments are relatively safe, can lead to radiographic and clinical improvement, and result in good neurologic outcomes. These observations should be incorporated in future study designs.

Acknowledgments

The authors thank Alicia Ponce for her expert assistance. The patients profiled in this series were patients at the Children's Medical Center Dallas and were treated from the time of diagnosis or referral until discharge from the hospital. None of the work described herein took place at an extramural site. The data contained in this manuscript were presented at the 2010 meeting of the Southern Pediatric Neurology Society meeting. An earlier version of the abstract (without manuscript or figures) was published in the *Journal of Child Neurology* June 2010 issue.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: MMD was supported by the North and Central Texas Clinical and Translational Science Initiative from the NIH KL2 RR024983, First American Real Estate Information Services, Inc., and the Doris Duke Charitable Foundation. MMD and PP were supported by the Perot Center for Brain and Nerve Injury at Children's Medical Center Dallas.

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Figure 1.

Thrombolytic infusion resolves sinus thrombosis. Prior to thrombolysis (A), note high-density clot within the straight sinus and torcula (arrowheads). Intraparenchymal pressure monitor was inserted at outside hospital (white arrow); there is no hemorrhage around the monitor. Two days into the infusion, repeat CT (B) shows blood along the tip of the monitor. The patient's neurologic status had improved somewhat since admission, and hyperdensity within the sinuses had resolved; the infusion was continued. Epidural venogram (C) shows thrombosis of the superior sagittal sinus. The tip of the 3-French microcatheter is in the anterior one-third of the sagittal sinus (white arrow). Egress of contrast is blocked by thrombus (arrowhead); contrast flows retrograde into superficial cortical veins (black arrow). Contrast-enhanced MR venogram (D) 5 days later showed flow within the sagittal and transverse sinuses. The patient is neurologically intact at follow-up.

Figure 2. Magnetic resonance (MR) venography is used to document extent of dural sinus thrombosis and degree of clot dissolution. Sagittal image from a 2-dimensional time-of-flight MR venography before treatment (A) shows thrombosis of the superior sagittal sinus (arrow). Clot is seen within the proximal straight sinus and the transverse sinuses (arrowheads). Follow-up MR venogram (B) shows widely patent dural venous sinuses and cerebral veins.

Table 1

Clinical, Imaging, Treatment, and Outcomes Data

Age, y	Medical Condition/ Risk Factor	Hypercoagulable State	Infarct?	Rabinstein Score	Initial Presentation — At Treatment	Dose/Duration of tPA	Hemorrhage Following Thrombolysis	RRQ (outcome)
17	Dehydration	Antiphospholipid antibodies, homozygous prothrombin mutation	No	7	Hemiparesis, focal seizure — coma	47 mg/24 h	Mild	0
15	Ectodermal dysplasia	Factor V Leiden heterozygote, low protein C activity	No	8	Loss of consciousness, strabismus — coma	61 mg/79 h	Moderate	0
9	ALL, asparaginase	Normal	Venous	2	Focal seizure — coma	14 mg/21 h	Treatment limiting	1.5
12	ALL, asparaginase, dehydration	None identified	Hemorrhagic and venous	6	Leg weakness — lethargic	11 mg/16 h	Mild	0
10	Trisomy 21, dehydration	Protein-losing enteropathy	Venous	6	Generalized weakness, focal seizure — coma	60 mg/102 h	None	0.5
12	Pilocytic, astrocytoma	Factor V Leiden heterozygote, antiphospholipid antibodies	No	9	Headache, decreased vision — coma	36 mg/54 h	Treatment limiting	7

Abbreviations: ALL, acute lymphocytic leukemia; tPA, tissue plasminogen activator; RRQ, Recurrence and Recovery Questionnaire, Parental Pediatric Stroke Outcome Measure (0–10 scale with 0 = normal).

Note: The Rabinstein score is derived from cerebral venography and assigns 1 point for each involved sinus; higher numbers indicate more widespread thrombosis (see Methods).