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Endovascular treatment of cerebral venous thrombosis involving the deep venous system

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Abstract

Background: Cerebral venous thrombosis (CVT) is a rare but important cause of stroke. The superficial venous sinuses, including the superior sagittal sinus, are the most common location of CVT. Thrombosis of the deep venous system occurs less frequently, but can be more clinically severe by causing disturbances of consciousness due to involvement of deep anatomic structures including the thalamus and basal ganglia, leading to a higher incidence of death and disability. While anticoagulation is the standard initial recommended therapy for patients with CVT, endovascular intervention is sometimes proposed to help relieve cerebral venous hypertension.

Methods: We performed a retrospective case series review of a single-center interventional database over a 13-year time period to identify cases of CVT that underwent endovascular therapy and analyzed clinical and radiographic characteristics of these patients.

Results: We identified 43 patients who underwent endovascular treatment for CVT. Twelve of these cases involved the deep system. Of the 12 patients in our consecutive case series, all 12 experienced recanalization of the deep system following catheter-directed alteplase infusions in the superficial or straight sinuses. On follow-up, these patients clinically did well in spite of initially poor neurologic examinations.

Conclusion: In this single-center retrospective case series of 12 patients with deep and superficial venous thrombosis, endovascular treatment with site-directed thrombolytic infusion of the superficial venous sinuses with or without catheterization of the straight sinus resulted in angiographic recanalization of the deep veins and improved radiologic and clinical outcomes in 100% of the patients.

Keywords

Cerebral venous thrombosis, cerebral venous sinus thrombosis, dural venous sinus thrombosis, deep cerebral venous thrombosis

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Introduction

Cerebral venous thrombosis (CVT) is a rare but important etiology of stroke that accounts for 0.5–1% of all strokes. While the superior sagittal sinus is the most common location for CVT, 10.9% of CVT involves the deep venous system including the internal cerebral veins, vein of Galen, basal vein of Rosenthal, and thalamostriate veins.[1] Deep CVT is of particular concern as these patients have an increased prevalence of disorders of consciousness, largely due to edema, stroke, or intracerebral hemorrhage (ICH) in the thalamus and basal ganglia. This results in death of dependency in 29% of these patients.[2]

Among all patients with CVT who are critically ill, 36.8% have clots in deep cerebral veins, further demonstrating the severity of this disease.[3] While anticoagulation is the standard initial recommended therapy for patients with CVT, endovascular intervention is sometimes proposed to help relieve cerebral venous hypertension. However, direct catheterization of the deep venous system is challenging due to anatomical navigation and the size and fragility of these vessels.

In our institutional experience with severe symptomatic cases of both superficial and deep venous thrombosis, endovascular treatment with catheter-directed thrombolytic infusion of the superficial venous sinuses with or without also catheterization of the straight sinus routinely results in angiographic recanalization of the deep venous sinuses leading to improved radiographic and clinical outcomes. The goal of this study was to retrospectively

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evaluate the clinical outcomes for a consecutive case series of patients with deep CVT who received endovascular therapy at our institution.

Methods

We performed a retrospective case series analysis by searching our interventional radiology (IR) database from 1 January 2010 to 31 December 2023 for patients with CVT using search terms "cerebral venous thrombosis," "dural venous sinus thrombosis," and "cerebral venous sinus thrombosis." We then refined the search by reviewing the procedure reports for terms "endovascular" and "deep." Next, we reviewed reports for evidence of deep DVT. Finally, we performed a chart review of the included patients to determine clinical and radiographic outcomes. This study was approved by the Institution Review Board (IRB) under on 02/16/2021. This is an IRB-approved retrospective study, all patient information was de-identified and patient consent was not required. Patient data will not be shared with third parties.

Results

The initial search of the IR database yielded a total of 5599 patient encounters. A search of the associated procedure reports yielded 43 patients who underwent endovascular treatment for CVT. Of these, 31 patients had CVT confined to the superficial sinuses only. Twelve patients also had venous thrombosis involving the deep system and were included for chart review. Table 1 shows the demographic information of the patient.

Table 1. Demographics and clinical characteristics of the 12 patients whose CVT involved deep veins and who underwent endovascular intervention.

Average AGE	35.6 years
Sex	5 male, 7 female
Initial presentation	10 headache
	4 nausea/vomiting
	3 focal motor deficits
	2 dizziness
	1 syncope
	2 gait difficulty
	6 altered mental status
Initial neurologic examination	5 normal
	3 focal motor deficits
	6 disorders of consciousness
Initial non-vascular neuroimaging	6 normal
	1 ICH
	1 subdural hematoma
	2 ischemic stroke
	4 cerebral edema
	3 thalamic involvement
Indication for intervention	7 neurologic decline
	4 ischemic stroke
	2 ICH
	2 extensive clot burden

CVT: cerebral venous thrombosis; ICH: intracerebral hemorrhage.

All 12 patients with deep CVT underwent catheter-directed intervention due to clinical and/or radiographic worsening despite adequate heparin infusions. Four of these patients underwent catheterization not only of the superficial sinuses, but also of the straight sinus. All other interventions were in the superficial venous sinuses only. All 12 patients were treated with microcatheter alteplase infusions through up to three different microcatheters positioned in contiguous clot outside of the deep system. The average duration of microcatheter alteplase infusions was 2.8 days. Treatment characteristics of the patients is outlined in Table 2. All 12 patients with deep venous involvement ultimately had recanalization of the deep system. Table 3 describes the clinical outcomes. Modified Rankin Scale (mRS) at discharge was an average of 2.2 and a median of 2 (range 0–5). Figure 1 demonstrates cerebral angiography of one of the patients before and after treatment. Similarly, Figure 2 shows select MRI brain sequences of a different patient before and after treatment, again exemplifying radiographic resolution.

Discussion

All 12 of the patients in our consecutive case series experienced recanalization of the deep system following catheter-directed alteplase infusions in the superficial and/or straight sinuses. On follow-up, these patients clinically did well, in spite of initially poor neurologic examinations, with a mean and median follow-up mRS of 2.2 and 2, respectively.

Our results suggest that more aggressive interventions for deep CVT, such as catheter-directed alteplase infusions, could be of benefit for patients with this condition who are at risk of poor clinical and radiographic outcomes. Patients with deep CVT may represent a subgroup that can benefit from endovascular intervention, as up to 72% present with disorders of consciousness, which can result in mortality as high as 53%.[2,4] Further emphasizing

Table 2. Treatment characteristics of the 12 patients whose CVT involved deep veins and who underwent endovascular intervention.

Initial treatment	Unfractionated heparin infusion all 12 patients
Endovascular techniques (some >1 technique)	Alteplase infusion all 12 patients
	6 mechanical thrombectomies
	1 angioplasty
Average # repeat cerebral angiograms	4 (1–8)
Average duration thrombolytic microcatheters (Days)	2.8 (1–7)
Catheterization included straight sinus	4
Catheterization only superficial sinuses	8

CVT: cerebral venous thrombosis.

the dangerous nature of deep CVT, a 624 patient natural history registry of deep CVT showed a hazard ratio for death or dependency of 2.92, while another study showed deep CVT to have an adjusted odds ratio of 5.43 as an independent predictor of poor outcome.[1,5] Poor clinical outcomes likely stem from the most common radiologic parenchymal lesion, which is thalamic edema, found in 69% of patients.[6] Another case series of 156 patients further reflects severity by demonstrating that 30% of patients with CVT had poor outcomes if they had factors including ICH, rapidly progressive neurologic deficits, or involvement of the deep venous system.[7] These data suggest patients with deep CVT are in need of aggressive interventions to mitigate a more devastating prognosis.

Table 3. Clinical outcomes of the 12 patients whose CVT involved deep veins and who underwent endovascular intervention.

Technical complications	1 femoral artery pseudoaneurysm 1 internal carotid artery pseudoaneurysm
Sequalae of CVT	4 ischemic strokes 3 ICH 2 thalamic venous congestion
Average ICU length of stay (days)	15.4 (3–50)
Recanalization deep system	All 12 patients
Average mRS at discharge	2.2 (range 0–5)
Median mRS at discharge	2 (range 0–5)

CVT: cerebral venous thrombosis; ICH: intracerebral hemorrhage; mRS: Modified Rankin Scale.

Thrombus location can be variable in patients presenting with CVT. Even though deep venous involvement is often associated with clot also in superficial locations, the deep involvement is an isolated finding in 28% of patients.[4] 97% of these patients with deep involvement also had involvement of the straight sinus.[6] Thrombus location guides interventional strategies. In superficial CVT, direct access to the clot often renders thrombectomy

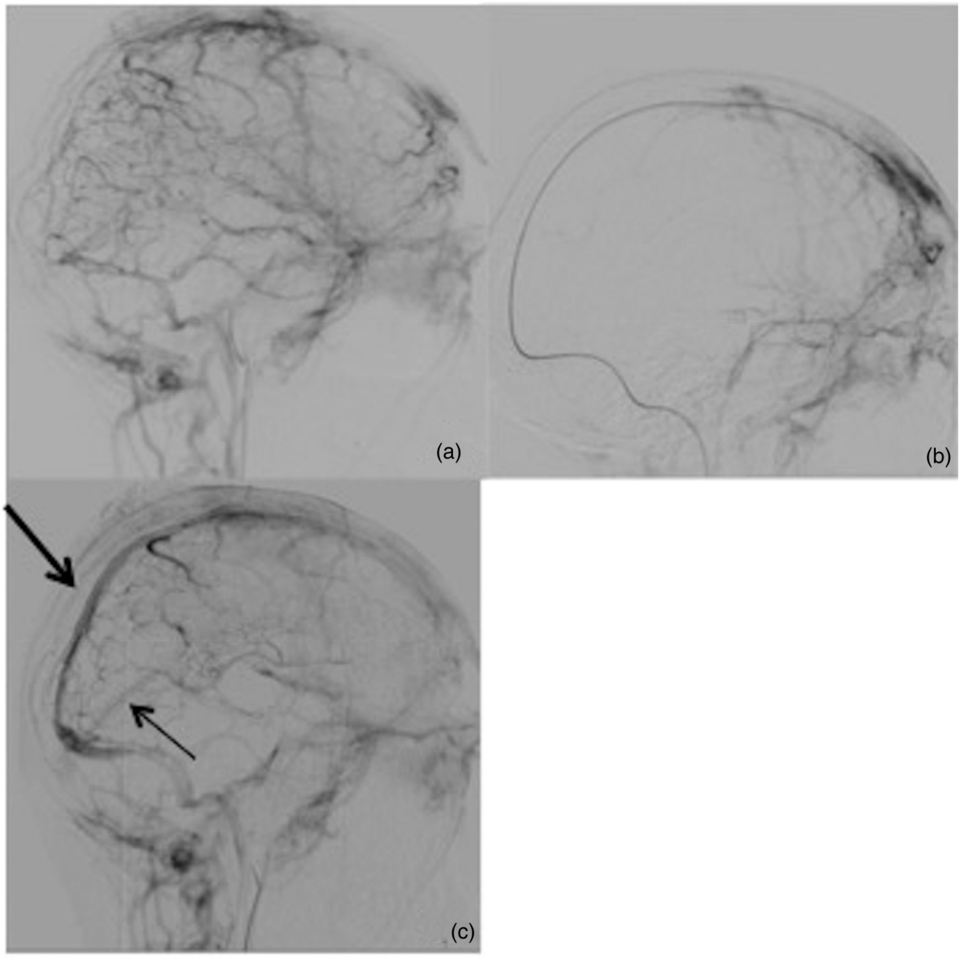

Figure 1. Angiography images of a 25-year-old male with CVT and altered mental status requiring intubation for airway protection. (a) Pre-treatment venous phase arteriogram with thrombus in the superior sagittal sinus and deep venous system, (b) microcather venography of anterior superior sagittal sinus and subsequent microcatheters left with alteplase infusion for 3 days, (c) post-treatment venous phase arteriogram showing recanalization of the superficial and deep veins with now well opacified superior sagittal sinus (thick arrow), straight sinus (thin arrow), and deep venous system. CVT: cerebral venous thrombosis.

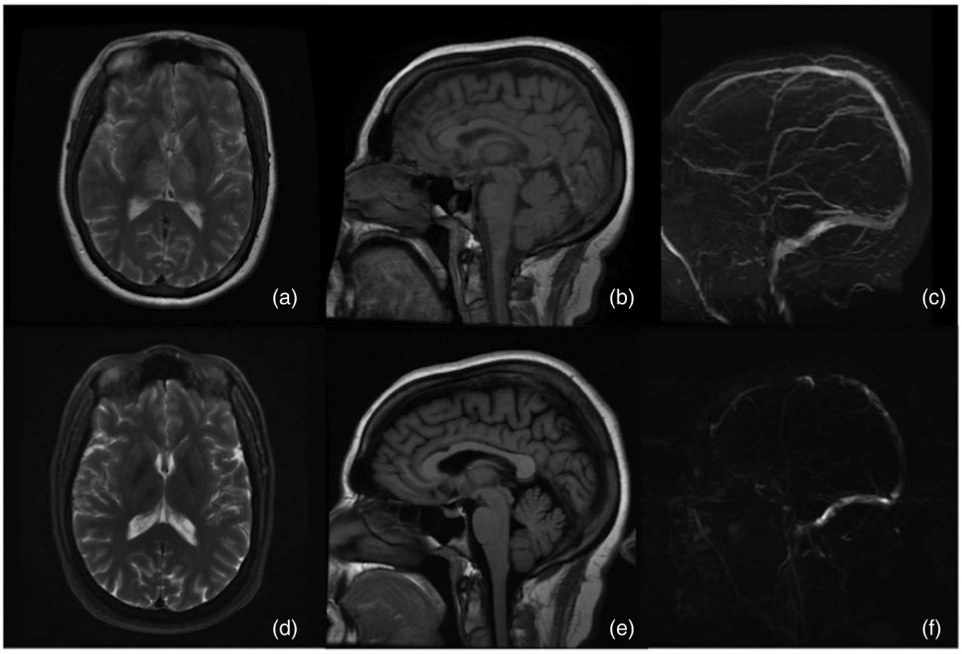

Figure 2. A 36-year-old female presenting with headache found to have CVT involving the deep venous system, straight sinus, left transverse sinus, left sigmoid sinus, and left internal jugular vein who underwent alteplase infusions via microcatheters positioned in the straight sinus, left transverse sinus, and left sigmoid sinus for 3 days with significant recanalization. (a) Pre-treatment T2 MRI brain showing bilateral thalamic edema, (b) pre-treatment T1 FLAIR MRI brain showing hyperintense thrombi in the straight sinus and deep venous system, (c) pre-treatment MRA brain showing no signal in the straight sinus or deep venous system, (d) post-treatment T2 MRI brain showing improvement of bilateral thalamic edema, (e) post-treatment T1 FLAIR MRI brain showing resolution of hyperintense signal in the straight sinus and deep venous system, and (f) post-treatment MRA brain showing return of signal to the straight sinus and deep venous system. CVT: cerebral venous thrombosis.

successful, whereas in deep CVT the difficulty and safety considerations of catheterization may necessitate leaving microcatheters for prolonged alteplase infusion.

Indications for when to pursue endovascular therapy for any location of CVT have not been well established in guidelines or literature. At our institution, we have traditionally pursued endovascular treatment in the setting of clinical and/or radiographic worsening in spite of adequate unfractionated heparin infusions. Success has been demonstrated with this strategy in the literature. For example, among 185 patients with CVT who underwent thrombectomy, a mRS of 0–2 occurred in 84%, with near-complete recanalization in 74% and no recanalization in only 5%.[8] Another review of 120 patients specifically with deep CVT showed successful recanalization was associated with good functional outcomes and inversely related to mortality.[9] However, the benefits of therapy must be weighed against risks associated with intervention. A study of 235 patients who underwent endovascular treatment for CVT cited complete radiographic resolution in 69.0% of patients, with worsening or new ICH in 8.7% and catheter-related complications such as sinus perforation in 6.3%. In another review of 33 studies involving 610 patients who underwent endovascular treatment of CVT, 85% had good functional outcomes, with 62% experiencing recanalization; however, with a 5% all-cause mortality rate and a 3% catheter-related complication rate.[10] These studies cited failure of systemic anticoagulation, extensive clot burden, cerebral edema, elevated intracranial pressure, altered mental status, and progressively worsening focal neurologic deficits as indications to pursue thrombectomy.[11] These reviews present a compelling role for endovascular intervention in appropriately selected patients.

However, endovascular therapy is not the standard and may not be beneficial. The 2020 TO-ACT randomized-controlled trial compared patients randomized to endovascular treatment vs. medical therapy for CVT. It measured a primary endpoint of mRS 0–1 at 12 months, as well as recanalization rates. Only 67 patients were enrolled. The study found no difference between the treatment groups for the primary clinical outcome or the rate of symptomatic ICH. The trial was stopped early due to interim analysis showing pre-defined futility. This resulted in groups too small for a powered subgroup analysis, although there was a trend that patients in a coma state —likely indicative of deep thrombus involvement—may do better with endovascular therapy. In this study, only 9% of patients underwent continuous infusion of thrombolytic, while the most common endovascular technique, mechanical thrombectomy, was used in 91% of patients.[12] Alternatively, in our case series, all patients were treated with continuous alteplase infusions, which may be a more effective treatment for patients with deep CVT.

It has been suggested that delaying endovascular therapy and using it as a rescue intervention may make the lesions more resistant as the clot becomes chronic and thus less likely to achieve recanalization.[13] However, the poor clinical outcomes that result from inaction may compel instead early decision action, especially among the cohort of patients with deep CVT.

A variety of endovascular techniques including rheolytic therapy, balloon angioplasty, aspiration thrombectomy, balloon thrombectomy, and stent retriever thrombectomy have been attempted to treat CVT. While there is no firmly established clinical indication or technique for endovascular intervention, we propose using catheter-directed alteplase infusions through microcatheters positioned in the superior sagittal sinus, torcula, straight sinus, and/or transverse sinuses in cases of deep system involvement. The central proposed mechanism is that the alteplase diffuses throughout the extent of the clot lysing in both the superficial and the deep system.[14,15] Patients with microcatheter infusions remain under close watch in the intensive care unit between trips to the angiography suite to monitor progress and evaluate for the appropriate timing of catheter removal once recanalization has been achieved. This particular technique has been studied in a 2022 review, which demonstrated a 95.2% rate of radiographic resolution and 72.2% rate of good clinical outcome, with a mRS of 0–2 at discharge. This was in spite of a 10.3% complication rate, including ICH, catheter-associated complications, edema, herniation, infarction, or re-thrombosis, although some of these complications may be accounted for by the natural progression of the disease.[16] A smaller study of 15 patients who underwent initial endovascular treatment not resulting in recanalization focused on continuous alteplase infusion as a secondary rescue technique. Ten of these patients subsequently underwent prolonged intraarterial alteplase infusions for 13–22 h. Follow-up angiography demonstrated complete recanalization in 4 of the 10, while 6 of the 10 had improvement in recanalization, and no patients had ICH.[17] These studies demonstrate that thrombolytic infusion may be the crux of endovascular strategy for deep CVT.

Limitations of this study include that it was performed at a single center, resulting in a relatively small sample size. This was also a retrospective case series evaluation. However, CVT and in particular deep CVT is a rare disease, and these results suggest a successful treatment solution for an otherwise debilitating condition.

Acknowledging that anticoagulation is the standard of care for treating CVT, endovascular therapy, in particular continuous alteplase infusions in severe cases where the deep system is involved, may play an important role with appropriate patient selection. Deep CVT patients treated with microcatheter alteplase infusions have been shown to have improvement in radiographic and clinical outcomes.

Conclusions

In this single-center retrospective case series of 12 patients with deep and superficial venous thrombosis, endovascular treatment with site-directed thrombolytic infusion of the superficial venous sinuses with or without catheterization of the straight sinus resulted in angiographic recanalization of the deep veins and improved radiologic and clinical outcomes in 100% of the patients.

Author contributor

All authors contributed substantially to the conception, data collection, writing, and/or review of this 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

This study was approved by the University of Colorado Multiple Institution Review Board under COMIRB Protocol 21-2797 on 02/16/2021. This is an IRB-approved retrospective study, all patient information was de-identified and patient consent was not required. Patient data will not be shared with third parties.

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References

1. Ferro JM, Canhão P, Stam J, et al. Prognosis of cerebral vein and dural sinus thrombosis: results of the International Study on Cerebral Vein and Dural Sinus Thrombosis (ISCVT). *Stroke* 2004; 35: 664–670.
2. Qiu Z, Sang H, Dai Q, et al. Endovascular treatments for cerebral venous sinus thrombosis. *J Thromb Thrombolysis* 2015; 40: 353–362.
3. Kowoll CM, Kaminski J, Weiß V, et al. Severe cerebral venous and sinus thrombosis: clinical course, imaging correlates, and prognosis. *Neurocrit Care* 2016; 25: 392–399.
4. Pfefferkorn T, Crassard I, Linn J, et al. Clinical features, course and outcome in deep cerebral venous system thrombosis: an analysis of 32 cases. *J Neurol* 2009; 256: 1839–1845.
5. Girot M, Ferro JM, Canhão P, et al. Predictors of outcome in patients with cerebral venous thrombosis and intracerebral hemorrhage. *Stroke* 2007; 38: 337–342.
6. Luo Y, Tian X and Wang X. Diagnosis and treatment of cerebral venous thrombosis: a review. *Front Aging Neurosci* 2018; 10: 2.
7. Guo X, Sun J, Lu X, et al. Intrasinus thrombolysis for cerebral venous sinus thrombosis: single-center experience. *Front Neurol* 2019; 10: 1185.
8. Siddiqui FM, Dandapat S, Banerjee C, et al. Mechanical thrombectomy in cerebral venous thrombosis: systematic review of 185 cases. *Stroke* 2015; 46: 1263–1268.
9. Yeo LL, Lye PP, Yee KW, et al. Deep cerebral venous thrombosis treatment: endovascular case using aspiration and review of the various treatment modalities. *Clin Neuroradiol* 2020; 30: 661–670.

10. Nepal G, Kharel S, Bhagat R, et al. Safety and efficacy of endovascular thrombectomy in patients with severe cerebral venous thrombosis: a meta-analysis. *J Cent Nerv Syst Dis* 2022; 14: 11795735221131736.
11. Ilyas A, Chen CJ, Raper DM, et al. Endovascular mechanical thrombectomy for cerebral venous sinus thrombosis: a systematic review. *J Neurointerv Surg* 2017; 9: 1086–1092.
12. Coutinho JM, Zuurbier SM, Bousser MG, et al. Effect of endovascular treatment with medical management vs standard care on severe cerebral venous thrombosis: the TO-ACT randomized clinical trial. *JAMA Neurol* 2020; 77: 966–973.
13. Goyal M, Fladt J, Coutinho JM, et al. Endovascular treatment for cerebral venous thrombosis: current status, challenges, and opportunities. *J Neurointerv Surg* 2022; 14: 788–793.
14. Yamini BM, Loch Macdonald R and Rosenblum J. Treatment of deep cerebral venous thrombosis by local infusion of tissue plasminogen activator. *Surg Neurol* 2001; 55: 340–346.
15. Kim SY and Suh JH. Direct endovascular thrombolytic therapy for dural sinus thrombosis: infusion of alteplase. *AJNR Am J Neuroradiolgy* 1997; 18: 639–645.
16. Paybast S, Mohamadian R, Emami A, et al. Safety and efficacy of endovascular thrombolysis in patients with acute cerebral venous sinus thrombosis: a systematic review. *Interv Neuroradiol* 2022; 30: 746–758.
17. Qureshi AI, Grigoryan M, Saleem MA, et al. Prolonged microcatheter-based local thrombolytic infusion as a salvage treatment after failed endovascular treatment for cerebral venous thrombosis: a multicenter experience. *Neurocrit Care* 2018; 29: 54–61.