

# Chapter 40

## Cerebral Venous Sinus Thrombosis



Benjamin Atchie and Don Frei

Cerebral venous sinus thrombosis (CVST) describes focal or diffuse clot formation within the intracranial venous sinuses of the brain. The diagnosis of CVST is rare with a reported rate ranging from 3 to 15 patients per million people per year. As such, there is sparse evidence available to help guide therapeutic strategies. It is therefore important to have a well-developed understanding of the pathophysiology, the myriad of potential underlying causes, and clinical features and imaging features that may be helpful in determining the best treatment options. Additionally, as is true with most other cerebrovascular disorders, cerebral venous sinus thrombosis management is best guided by a multidisciplinary team of providers including neurologists, neurosurgeons, and neuroradiologists, with a treatment plan tailored to the individual patient.

### Epidemiology

Recent reports indicate an absolute incidence of CVST as high as 15.7 cases per million people per year [1]. Observationally this is consistent with an increasing trend over the past 3 decades with a rate of 13.2 per million people per year identified in a multicenter study from the Netherlands from 2008 through 2010 and an estimated rate of <10 per million people per year in a retrospective analysis from Saudi Arabia from 1985 through 1994 [2, 3]. Whether this trend reflects a true increase in incidence of CVST or increased awareness and availability of improved noninvasive imaging remains unclear. Though these new reports suggest a significantly higher incidence than the widely accepted 3–4 cases per million people per year, CVST still remains a relatively uncommon diagnosis with the reported ratio of venous to arterial strokes being 1:62.5 [3, 4].

---

B. Atchie · D. Frei (✉)

Department of Neuro-Interventional Surgery, RIA Neurovascular, Englewood, CO, USA  
e-mail: [Benjamin.atchie@riaco.com](mailto:Benjamin.atchie@riaco.com); [don.frei@riaco.com](mailto:don.frei@riaco.com)

© Springer Nature Switzerland AG 2019

A. M. Spiotta et al. (eds.), *Management of Cerebrovascular Disorders*,  
[https://doi.org/10.1007/978-3-319-99016-3\\_40](https://doi.org/10.1007/978-3-319-99016-3_40)

623

Patient demographics are not homogenous with regard to the prevalence of CVST development. Unlike many other cerebral vascular diseases, CVST generally affects an otherwise healthy subset of younger adults; however, it is worth noting that this claim is heavily influenced by the incidence of CVST in young females of childbearing age. In fact, females are more likely to be diagnosed than males at a rate of 3:1, a statistic believed to reflect the hypercoagulable state induced by pregnancy and even more so by the frequency of oral contraceptive use [5]. To further emphasize this point, a publication by Ameri and Bousser has reported a uniform age distribution in men presenting with CVST, whereas 61% of women with CVST were between the ages of 20 and 35 [6, 7].

## Etiology

There are a number of risk factors associated with the development of CVST. In the majority of patients, approximately 70–80%, an underlying etiology will be found. Most commonly, a hypercoagulable condition is the instigating cause, and this may either be inherited or acquired. Over 100 predisposing hypercoagulable conditions have been identified; a list of common inherited and acquired hypercoagulable conditions is provided (Table 40.1). As stated previously, OCP use is one of, if not, the most frequently encountered risk factors; however, retrospective reviews have demonstrated more than one underlying cause in over a third of all patients presenting with cerebral venous thrombosis [8]. As such, a thorough investigation and a broad hypercoagulability work-up are mandated in every patient in order to uncover any and all predisposing risk factors and guide management.

Other less frequently encountered but well-established etiologies of CVST include head trauma and infection. With regard to head trauma, acute posttraumatic CVST is almost always associated with skull fractures that extend to the sinus or jugular foramen; however, there are case reports describing the delayed development of CVST even in the absence of a fracture [9, 10]. Similarly, CVST produced by local infection is rare in the modern era of antibiotics. When thrombophlebitis of the dural venous sinuses is suspected, the source is from the trans-osseous extension by a local infection, usually of the paranasal sinuses or middle ear, and it is in most cases readily identifiable.

Recently there has been an increasing awareness of the apparent effects of altitude on the development of CVST as well as venous thrombosis in other locations, but the data is limited to isolated case reports. Commonalities between these case reports suggest that the risk for CVST is increased in climbers who reach altitudes of about 5000 meters. Potential causalities include hypobaric hypoxia at extreme altitude, which can precipitate thrombosis through increased blood viscosity due to a secondary polycythemia, as well as an induced hypercoagulable state from increased factor VIIa activity and platelet activation [11–13].

Not to be understated is the risk dehydration may play. There are several reports citing a seasonal variation in the development of CVST, with increased incidence of

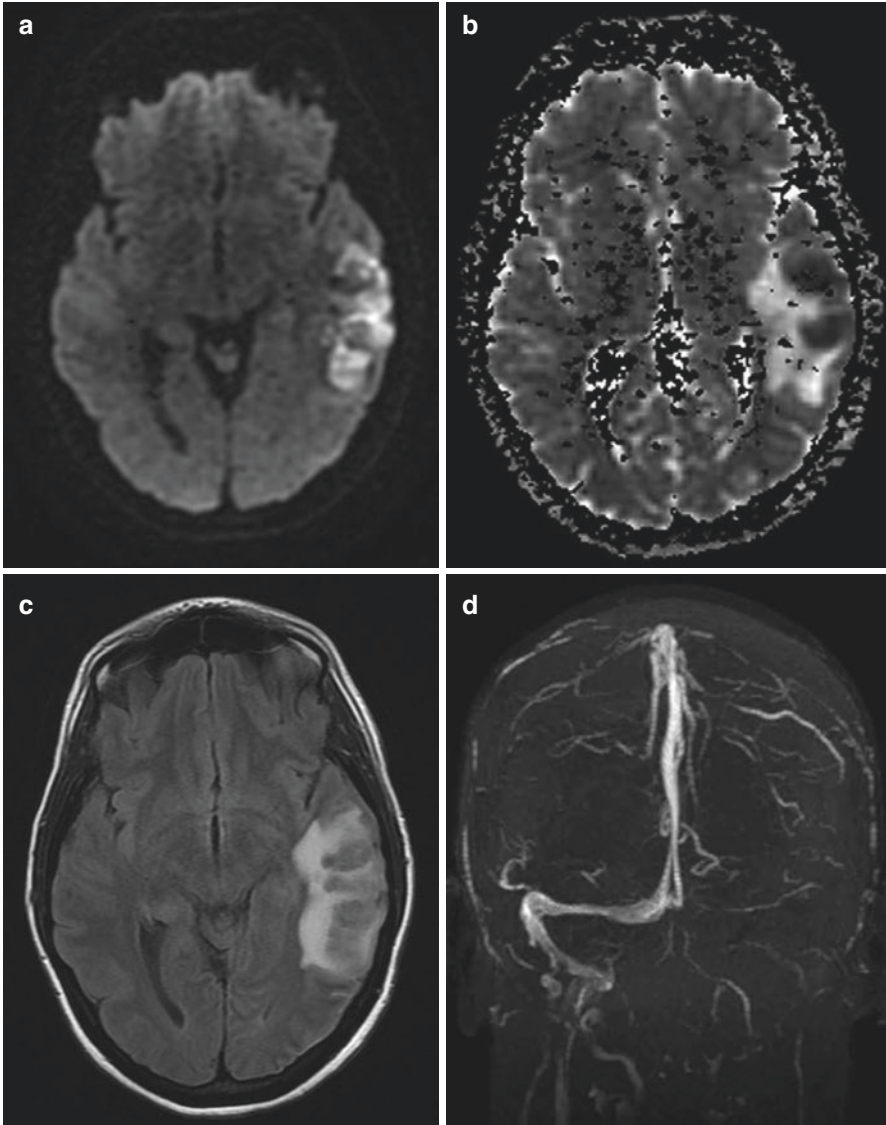
**Table 40.1** Risk factors for the development of CVST

Hormones
Oral contraceptives
Pregnancy and puerperium
Steroids
Hormone replacement therapy
Thyroid disease
Prothrombotic hematologic disorders
Antithrombin III deficiency
Protein C deficiency
Protein S deficiency
Antiphospholipid and anticardiolipin antibodies
Hyperhomocysteinemia
Systemic conditions
Cancer (local compression or hypercoagulable state)
Local infections (mastoiditis, sinusitis, the neck, etc.)
Nephrotic syndrome
Systemic lupus erythematosus
Behcet's disease
Inflammatory bowel disease
Sarcoidosis
Mechanical
Trauma
Lumbar puncture
Epidural blood patch

CVST during high-temperature months which indirectly implicates dehydration as a contributing factor [14]. Caution is advised however in labeling dehydration as the sole culprit when no other etiologies can be found as there is little direct evidence to support that dehydration alone is enough to potentiate venous thrombus formation [15].

## Pathogenesis

Vasogenic edema, venous infarct, and hemorrhage are directly related to cortical cerebral venous thrombosis and impaired venous outflow. Vasogenic edema is a result of the disruption of the blood-brain barrier and leaking of plasma into the intercellular space. This can present clinically with headaches, as a focal neurologic deficit, or with seizure, but is generally considered reversible. If prolonged or severe, the obstruction to venous outflow can eventually lead to irreversible cytotoxic edema as a result of local ischemia leading to cell death. MRI has been demonstrated as a useful tool in differentiating these two, often overlapping, phenomena [16] (Fig. 40.1). Cytotoxic edema in turn can predispose to petechial hemorrhages that can expand, often suddenly, into large lobar hemorrhages.



**Fig. 40.1** Diffusion-weighted image (a) and apparent diffusion coefficient map (b) demonstrating restricted diffusion consistent with cytotoxic edema. A T2-FLAIR image (c) also shows the extent of surrounding, potentially reversible, vasogenic edema. MR venography (d) confirming the presence of a left transverse and sigmoid sinus thrombosis

The role cerebral venous thrombosis plays in the development of intracranial hypertension and dural arteriovenous fistula is less well established. It is believed that the obstruction to venous outflow caused by dural venous sinus thrombosis leads to increased venous pressures which decreases the absorption of cerebral spinal fluid and results in increased intracranial pressures [4]. The resulting venous

hypertension that develops after venous thrombosis is also postulated to cause enlargement of microvascular connections within the dura as the body attempts to reroute the venous flow around the occlusion. Physiologic arteriovenous shunts have been described within the dural walls of the venous sinuses, and as these microvascular connections within the dura enlarge, these shunts may inadvertently capture this rerouted venous flow and develop into large dural AV shunts, further pressurizing the venous system [17].

## Clinical Presentation

The clinical presentation of CVST is often varied and nonspecific. It is not entirely surprising then that it is often overlooked and commonly misdiagnosed in routine clinical practice. Small retrospective case reports demonstrate a “miss rate” of up to 45% [18].

Headache is the most frequent and often the only symptom at presentation, with an incidence of 75–95% in patients with CVST. These headaches range in severity but generally worsen over the course of a few days eventually becoming severe enough for patients to seek medical attention. Rarely they can present acutely, and occasionally patients report them as “the worst headache of my life,” mimicking the presentation of subarachnoid hemorrhage. The source of these headaches is felt to be related to the resultant increased intracranial pressure, and not an inflammatory reaction to the thrombus or occlusion of the sinus itself. This is corroborated by the general inability of the headache to localize to the underlying thrombosed sinus. In fact, there appears to be almost no association between location of the headache and site of sinus thrombosis with the exception of the sigmoid sinus involvement, where 61% of patients with sigmoid sinus thrombosis report occipital headaches and neck pain [19]. Other nonspecific symptoms related to increased intracranial pressure are nausea and vomiting, which are also commonly seen in association with CVST.

Perhaps the most clinically apparent and readily available assessment of elevated intracranial pressure is the presence of papilledema which is observed in nearly a third of cases. Diplopia may also be present in 14% of patients when the intracranial pressure becomes so elevated that it produces downward displacement of the brain stem and stretches the sixth cranial nerves that are tethered in Dorello’s canal [20].

Other frequently encountered symptoms that are not related to elevated intracranial pressure are instead related to parenchymal injury secondary to hemorrhage, infarct, or vasogenic edema. Typical manifestations include seizures and focal neurologic deficit which develop in as many as half of all patients. Seizures are usually self-limited and focal, rarely progressing to a more generalized seizure. Focal impairments such as hemiparesis and aphasia are present in a minority of patients but are characteristic and, not surprisingly, correlate to the location of the thrombus. A classically described presentation is that of unilateral hemiparesis that progresses to bilateral hemiparesis over the course of a few days due to the involvement of the sagittal sinus [21]. Deep venous sinus involvement is less common, but patients with thrombosis of the straight sinus or vein of Galen may exhibit symptoms related

to thalamic or basal ganglia injury such as lethargy, disorientation, amnesia, occasionally oculomotor disturbances, and often rapid neurological deterioration.

In the 624 patients included in international study on cerebral vein and dural sinus thrombosis (ISCVT), the superior sagittal sinus was the most commonly involved sinus (62%) followed by the transverse sinus (41–45%) and the straight sinus (18%). Thrombosis of more than one sinus was also frequently encountered (30%).

## Diagnosis

Noninvasive imaging is paramount in establishing the diagnosis of CVST. Although a noncontrast head CT is typically the first study performed on patients with symptoms suggestive of CVST, it is insufficient to exclude the diagnosis and may be normal in more than two thirds of patients [22]. When positive, the most common findings include evidence of cerebral edema, hemorrhage, and a hyperdense cortical vein or venous sinus.

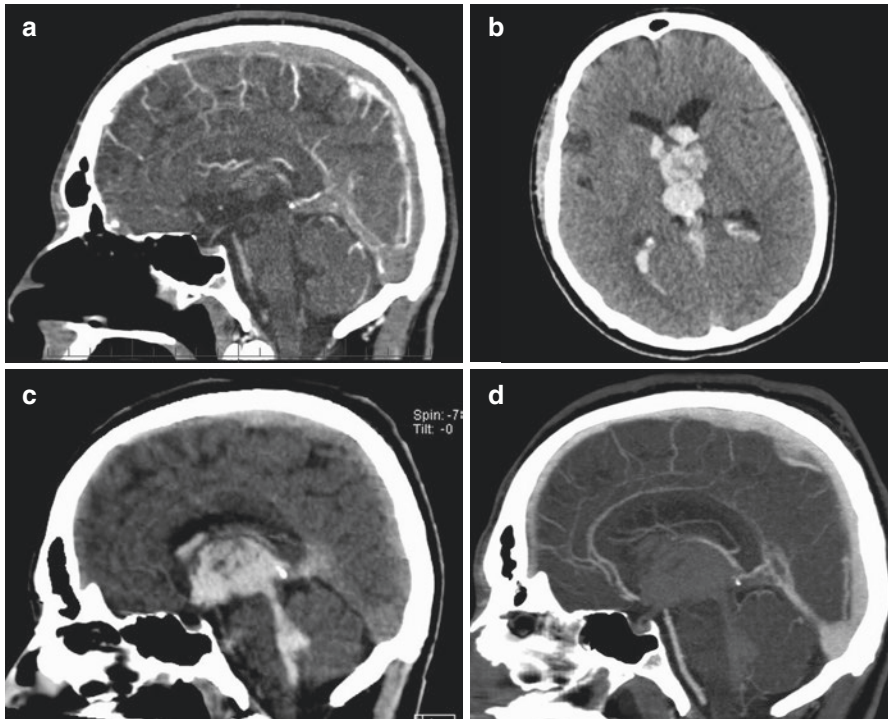
Due to wide availability, rapid acquisition, and ease of interpretation, the use of contrast-enhanced CT venography is becoming more widespread. It provides a highly detailed analysis of the cerebral venous system and provides equivalent sensitivity and specificity in making the diagnosis of dural sinus thrombosis, compared to non-enhanced “time-of-flight” MR venography [23] (Fig. 40.2). The same equivalency, however, has not yet been demonstrated in the comparison of CT venography to contrast-enhanced MR venography. Moreover, CT is inherently limited by the use of ionizing radiation and need for iodinated contrast [24].

MRI with the addition of MR venography is generally considered to be the gold standard in noninvasive imaging for the evaluation for CVST. MR venography delivers an accurate depiction of the intracranial dural venous sinuses and cortical veins. In addition to providing precise location and extent of sinus involvement, MRI and MRV can impart other clinically relevant information. Careful analysis can often suggest the age of the thrombus, and MRI can effectively evaluate the effects on the brain parenchyma. Parenchymal brain abnormalities have been identified in as many as 57% of patients with CVST and are more readily identified using MRI than CT. As eluded to previously, MRI provides valuable differentiation between potentially reversible vasogenic edema and irreversible cytotoxic edema using diffusion-weighted techniques. Similar to ischemic infarcts, cytotoxic edema will demonstrate restricted diffusion with decreased ADC values. MRI findings suggesting cytotoxic edema are generally considered a poor prognostic indication [16, 24].

## Prognosis

Similar to the varied clinical presentation, there is an unpredictable progression of symptoms and wide diversity in ultimate clinical outcome. For instance, an isolated headache can suddenly worsen deteriorating into coma or death, while a





**Fig. 40.2** CT venography (a) showing extensive thrombosis filling the superior sagittal sinus and straight sinus. Axial (b) and sagittal (c) noncontrast CT examination revealing delayed thalamic hemorrhage with intraventricular extension despite systemic anticoagulation. CT venography (d) showing recanalized dural sinuses post-mechanical thrombectomy

patient presenting with focal neurological deficits may make a prompt and complete recovery [25]. As such, it can be as much a challenge counseling the patient and their families as it is triaging them.

There are a few valuable prognostic indicators. The international study on cerebral vein and dural sinus thrombosis (ISCVT) identified 8 variables predictive of an unfavorable outcome: age >37 years, presenting GCS <9, male gender, ICH on admission, deep venous system thrombosis, any underlying malignancy, or CNS infection. These factors can double, or even triple, the risk of disability or death. It is important to note that despite the importance imaging plays in the diagnosis of CVST, its prognostic value is limited. Clinical improvement is often seen before vessel recanalization, and complete improvement may occur even in the event of persistent dural occlusion [26].

Overall mortality and morbidity rates range from 9% to 44% in small single-center series; however, in ISCVT, the largest multicenter observational study, a death and dependency rate of 13.4% was found and only approached 50% in cases of treatment failure [20]. The diagnosis of CVT generally carries with it a relative favorable outcome for the majority of patients who receive adequate treatment.

## Treatment

Initial stabilizing and standard resuscitative measures should be provided to every patient presenting with CVST. Once recognized, a parallel process of symptomatic treatment (normalizing ICPs, seizure control, and pain relief) alongside investigation into predisposing causes should be rapidly initiated. The specific management of CVST, however, can be challenging given the variety of presenting symptoms, unique underlying causes, varying extent of disease, generally poor value prognostic indicators, and the wide range of clinical outcomes.

Prompt administration of anticoagulation therapy is a well-established treatment modality with a large observational dataset and is widely considered to be the current standard of care in most patients presenting with CVT. It should be noted, however, that there are only two available randomized controlled studies investigating the role of unfractionated heparin (UFH) and low-molecular-weight heparin (LMWH) in the treatment of CVT [27, 28]. It also should be pointed out that the study comparing LMWH to placebo did not show a statistical significance benefit of LMWH and the study comparing unfractionated heparin to placebo included only 20 patients. Criticism notwithstanding, these two studies did demonstrate one important point: the safety of anticoagulation in the treatment of CVT even in the setting of intracerebral hemorrhage. Since then a mountain of observational data has supported not only the safety of administering anticoagulation to patients with CVT, with and without ICH, but also a trend toward benefit [29]. This trend is so convincing that the likelihood for any future randomized controlled studies is low as they would probably be deemed unethical.

The rationale for anticoagulation revolves mainly around its ability to prevent thrombus propagation and to facilitate recanalization. There are no current recommendations of one agent over the other with regard to UFH vs. LMWH; however, a large meta-analysis evaluating the two medications for treatment of pulmonary thromboembolism has showed a safety benefit with LMWH, which had a lower risk of major hemorrhage (1.2% versus 2.1%) and death (4.5% versus 6.0%) [30]. There is also no specific data to suggest the optimal long-term anticoagulation agent or guide the duration of management, but a typical time course ranges from 3 to 12 months depending on the underlying cause for CVST.

Despite the efficacy of anticoagulation, there are those patients who will deteriorate despite best medical management alone. For these cases, there is an increasing interest in the role endovascular thrombectomy and thrombolysis might play in the treatment of CVST as an adjunctive or stand-alone therapy. The potential advantage of endovascular therapy over systemic therapy alone is the rapid resolution of thrombus resulting in normalization of venous flow and associated decrease in ICPs. How this is achieved varies by institution, and a variety of different techniques have been described.

The most studied endovascular technique is that of direct catheter thrombolysis. This technique is employed through the placement of a microcatheter into the affected sinus and delivery of a thrombolytic agent directly to the thrombus. A meta-



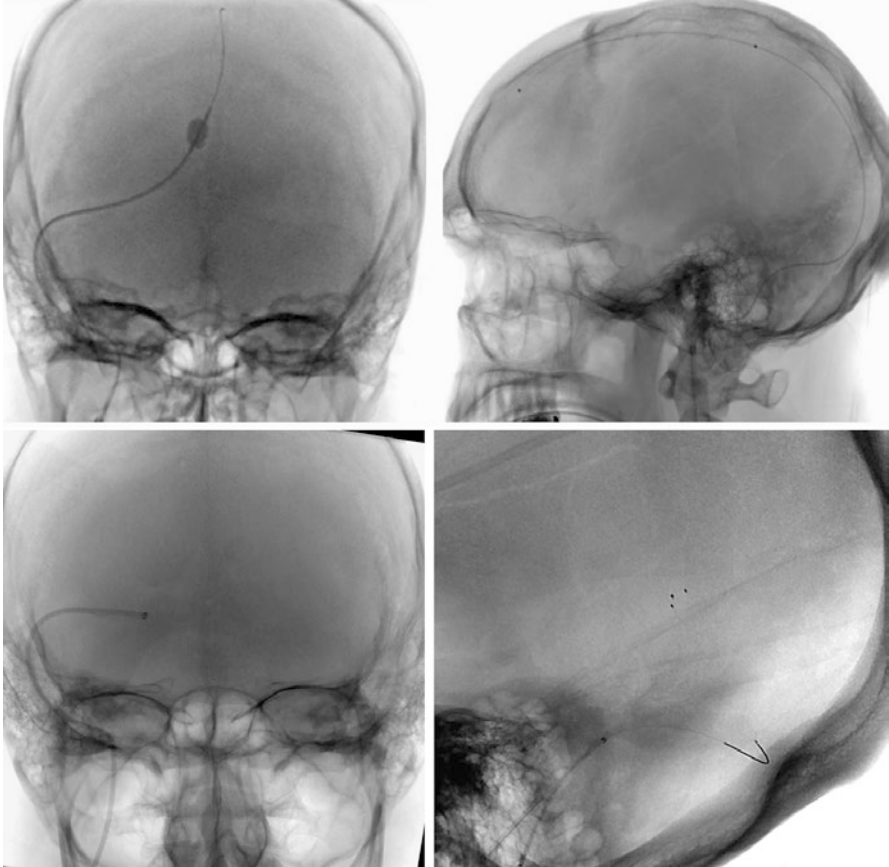
analysis that included 169 patients with CVST treated with local thrombolysis demonstrated potential benefit to critically ill patients [31]. In a small retrospective cohort compiled by Wasay et al., 20 patients who received systemic thrombolysis were compared with 20 patients who received catheter-directed thrombolysis. They showed improved outcomes at discharge in those patients who underwent catheter-directed thrombolysis with urokinase, but at the cost of an increased risk of developing ICH [32].

Other promising techniques including rheolytic and mechanical thrombectomy have since been developed along with the advent of newer endovascular devices. In fact, the only prospective endovascular study included 20 patients, of which the majority [15] were treated with a rheolytic catheter in combination with chemical thrombolysis. Rheolytic catheters use high-velocity saline jets to create a Bernoulli effect for thrombus dissociation and evacuation. In this study, directed thrombolysis/thrombectomy was shown to be effective but again appeared to increase the risk of ICH, possibly related to small vessel injury [33]. Other potentially less traumatic methods include mechanical embolectomy using a Fogarty balloon catheter (Fig. 40.3); (Edwards Lifesciences Corp, Irvine, CA) or the newer Penumbra aspiration catheters (Penumbra Inc., Alameda, California), but information on the use of these devices is limited.

Whichever endovascular method is employed, it is generally considered wise to use it in conjunction with systemic anticoagulation as opposed to stand-alone therapy. There is an ongoing trial, the TOACT (Thrombolysis or Anticoagulation for Cerebral Venous Thrombosis) trial, which is directly comparing endovascular therapy alone to systemic anticoagulation with heparin, but it remains to be seen; however, this will affect the current consensus on this particular clinical practice.

Because current data on the efficacy and safety of endovascular therapy consists only of isolated case reports and small case series, it is currently recommended, in a scientific statement by the American Heart Association and American Stroke Association, as treatment reserved for those patients who continue to deteriorate despite the use of anticoagulation or in patients who develop mass effect from venous infarction or ICH that causes intracranial hypertension resistant to standard therapies [29]. Perhaps a more robust algorithm in determining the appropriate use of endovascular treatment has been outlined by Rahman et al., which also takes into consideration the severity of the patient's clinical presentation through the use of the Glasgow Coma Scale (GCS). In their interpretation of the currently available data, patients who present with a GCS score  $\leq 8$  are strongly considered for immediate catheter-directed thrombolysis/thrombectomy, patients with GCS scores between 9 and 12 may be considered for immediate endovascular treatment, and patients with a GCS  $>12$  may be considered only after a trial of systemic anticoagulation [34]. Of course, as with the use of systemic medical management, neither of these recommendations have been validated with an appropriately designed randomized control trial and should be implemented cautiously.

Despite some interesting historical reports regarding the open surgical management of CVST, surgery has fallen from favor due to the emergence of effective medical and endovascular methods. It remains, however, an integral and critical



**Fig. 40.3** AP fluoroscopic image demonstrating placement of a Fogarty balloon for mechanical thrombectomy of a sagittal sinus and right transverse sinus thrombosis

component in the comprehensive treatment of patients with CVST who require decompressive craniotomies for large venous infarctions with elevated ICPs and for decompression of large hematomas.

## Summary

Cerebral venous sinus thrombosis is an uncommon diagnosis effecting as many as 15.7 patients per million people per year. It affects females more common than males on the order of 3:1, and in the majority cases, there is an underlying hypercoagulable state or underlying cause such as trauma or infection.

It has a varied clinical manifestation but common presenting symptoms, such as headache and seizures, which are generally nonspecific. Similarly, the natural his-

tory of cerebral venous sinus thrombosis varies widely from a benign self-limiting process to intracerebral hemorrhage and death. These potentially disastrous outcomes highlight the need for quick, accurate diagnosis and prompt management.

Though the mainstay of therapy for venous sinus thrombosis remains systemic anticoagulation, there is an increasing evidence to support adjunctive care with early endovascular treatment through catheter-directed thrombolysis and/or mechanical thrombectomy.

As with most cerebrovascular disorders, cerebral venous sinus thrombosis management is best guided by a multidisciplinary team of providers including neurologists, neurosurgeons, and neuroradiologists, with a treatment plan tailored to the individual patient.

## References

1. Devasagayam S, Wyatt B, Leyden J, Kleinig T. Cerebral venous sinus thrombosis incidence is higher than previously thought. *Stroke*. 2016;47:2180–2.
2. Coutinho JM, Zuurbier SM, Aramideh M, Stam J. The incidence of cerebral venous thrombosis: a cross-sectional study. *Stroke*. 2012;43:3375–7.
3. Daif A, et al. Cerebral venous thrombosis in adults. *Stroke*. 1995;26:1193–5.
4. Bienfait HP, Stam J, Lensing AW, van Hilten JJ. Thrombosis of the cerebral veins and sinuses in 62 patients. *Ned Tijdschr Geneeskd*. 1995;139:1286–91.
5. Filippidis A, Kapsalaki E, Patramani G, Fountas KN. Cerebral venous sinus thrombosis: review of the demographics, pathophysiology, current diagnosis, and treatment. *Neurosurg Focus*. 2009;27:E3.
6. Siddiqui FM, Kamal AK. Incidence and epidemiology of cerebral venous thrombosis. *JPak Med Assoc*. 2006;56:485–7.
7. Ameri A, Bousser MG. Cerebral venous thrombosis. *Neurol Clin*. 1992;10:87–111.
8. Yadegari S, Ghorbani A, Miri SR, Abdollahi M, Rostami M. Clinical features, risk factors, and outcome of cerebral venous thrombosis in Tehran, Iran. *J Neurosci Rural Pract*. 2016;7:554–8.
9. Delgado Almandoz JE, et al. Prevalence of traumatic dural venous sinus thrombosis in high-risk acute blunt head trauma patients evaluated with multidetector CT venography. *Radiology*. 2010;255:570–7.
10. Ghuman MS, Salunke P, Sahoo SK, Kaur S. Cerebral venous sinus thrombosis in closed head trauma: a call to look beyond fractures and hematomas! *J Emerg Trauma Shock*. 2016;9:37–8.
11. Song SY, et al. Cerebral thrombosis at altitude: its pathogenesis and the problems of prevention and treatment. *Aviat Space Environ Med*. 1986;57:71–6.
12. Bendz B, et al. Acute hypoxia and activation of coagulation. *Lancet*. 2003;362:997–8.
13. Shrestha P, Basnyat B, Küpper T, van der Giet S. Cerebral venous sinus thrombosis at high altitude. *High Alt Med Biol*. 2012;13:60–2.
14. Salehi G, Sarraf P, Fatehi F. Cerebral venous sinus thrombosis may follow a seasonal pattern. *J Stroke Cerebrovasc Dis*. 2016;25:2838–43.
15. Schreijer AJM, Reitsma PH, Cannegieter SC. High hematocrit as a risk factor for venous thrombosis. Cause or innocent bystander? *Haematologica*. 2010;95:182–4.
16. Yii IYL, Mitchell PJ, Dowling RJ, Yan B. Imaging predictors of clinical deterioration in cerebral venous thrombosis. *J Clin Neurosci*. 2012;19:1525–9.
17. Chaudhary MY, et al. Dural arteriovenous malformation of the major venous sinuses: an acquired lesion. *AJNR Am J Neuroradiol*. 1982;3:13–9.
18. Wang X, Sun X, Liu H. Clinical analysis and misdiagnosis of cerebral venous thrombosis. *Exp Ther Med*. 2012;4:923–7.

19. Wasay M, Kojan S, Dai AI, Bobustuc G, Sheikh Z. Headache in cerebral venous thrombosis: incidence, pattern and location in 200 consecutive patients. *J Headache Pain*. 2010;11:137–9.
20. Ferro JM, Canhão P, Stam J, Bousser M-G, Barinagarrementeria F. Prognosis of cerebral vein and dural sinus thrombosis: results of the International Study on Cerebral Vein and Dural Sinus Thrombosis (ISCVT). *Stroke*. 2004;35:664–70.
21. Stam J. Thrombosis of the cerebral veins and sinuses. *N Engl J Med*. 2005;352:1791–8.
22. Linn J, et al. Noncontrast CT in deep cerebral venous thrombosis and sinus thrombosis: comparison of its diagnostic value for both entities. *AJNR Am J Neuroradiol*. 2009;30:728–35.
23. Ozsvath RR, et al. Cerebral venography: comparison of CT and MR projection venography. *AJR Am J Roentgenol*. 1997;169:1699–707.
24. Leach JL, Fortuna RB, Jones BV, Gaskill-Shibley MF. Imaging of cerebral venous thrombosis: current techniques, spectrum of findings, and diagnostic pitfalls. *Radiographics*. 2006;26:S19–41.
25. Bentley JN, Figueroa RE, Vender JR. From presentation to follow-up: diagnosis and treatment of cerebral venous thrombosis. *Neurosurg Focus*. 2009;27:E4.
26. Bousser M-G. Cerebral venous thrombosis. *Stroke*. 1999;30:481–3.
27. Einhüpl KM, et al. Heparin treatment in sinus venous thrombosis. *Lancet*. 1991;338:597–600.
28. de Bruijn SFTM, Stam J. Randomized, placebo-controlled trial of anticoagulant treatment with low-molecular-weight heparin for cerebral sinus thrombosis. *Stroke*. 1999;30:484–8.
29. Saposnik G, et al. Diagnosis and management of cerebral venous thrombosis. *Stroke*. 2011;42:1158–92.
30. van Dongen CJ, van den Belt AG, Prins MH, Lensing A. In: Prins MH, editors. *Cochrane Database of Systematic Reviews*. CD001100. John Wiley & Sons, Ltd; 2004. <https://doi.org/10.1002/14651858.CD001100.pub2>
31. Canhão P, Falcão F, Ferro JM. Thrombolytics for cerebral sinus thrombosis: a systematic review. *Cerebrovasc Dis*. 2003;15:159–66.
32. Wasay M, et al. Nonrandomized comparison of local Urokinase thrombolysis versus systemic heparin anticoagulation for superior sagittal sinus thrombosis. *Stroke*. 2001;32:2310–7.
33. Stam J, Majoie CBLM, van Delden OM, van Lienden KP, Reekers JA. Endovascular thrombectomy and thrombolysis for severe cerebral sinus thrombosis. *Stroke*. 2008;39:1487–90.
34. Rahman M, Velat GJ, Hoh BL, Mocco J. Direct thrombolysis for cerebral venous sinus thrombosis. *Neurosurg Focus*. 2009;27:E7.