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MR Venography in the Diagnosis of Cerebral Venous Sinus Thrombosis: A Prospective Observational Study

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ABSTRACT

Background: Cerebral venous sinus thrombosis (CVST) is an uncommon but potentially life-threatening cerebrovascular disorder with diverse and often non-specific clinical presentations. Early and accurate diagnosis is essential for prompt initiation of anticoagulation and prevention of catastrophic neurological sequelae.

Objective: To evaluate the diagnostic utility of magnetic resonance venography (MRV) in detecting cerebral venous sinus thrombosis and to characterize the imaging findings and patterns of sinus involvement in clinically suspected patients.

Materials and Methods: This prospective observational study was conducted in the Department of Radiodiagnosis, Jawaharlal Nehru Medical College and Acharya Vinoba Bhave Rural Hospital, Sawangi (Meghe), Wardha, over a one-year period from July 2024 to June 2025. Fifty consecutive patients with clinical suspicion of CVST were imaged on a 1.5-Tesla MRI scanner using conventional brain sequences supplemented by 2D time-of-flight (TOF) MRV, 3D phase-contrast MRV, and post-contrast MR venography in selected cases. Imaging findings were correlated with clinical features and follow-up.

Results: Of the 50 patients evaluated, 32 (64%) had confirmed CVST. The mean age was 32.4 ± 11.6 years, with a female-to-male ratio of approximately 2.2:1. Headache (87.5%) was the most frequent presenting symptom, followed by seizures (43.7%) and focal neurological deficits (28.1%). The superior sagittal sinus was the most commonly involved sinus (62.5%), followed by the transverse (53.1%) and sigmoid sinuses (40.6%). Multiple sinus involvement was observed in 56.2% of cases. Parenchymal changes—including venous infarcts, edema, and hemorrhagic transformation—were identified in 46.8% of patients. Contrast-enhanced MRV demonstrated higher diagnostic confidence in delineation of cortical and deep venous involvement compared with TOF techniques, particularly in cases with slow flow or sinus hypoplasia.

Conclusion: MR venography, when combined with conventional MRI sequences, is a sensitive, specific, and non-invasive imaging modality for the diagnosis of CVST. Contrast-enhanced MRV is particularly useful in equivocal cases and should be employed when TOF or phase-contrast techniques yield ambiguous findings.

Keywords: *Cerebral venous sinus thrombosis; MR venography; Time-of-flight; Phase-contrast; Superior sagittal sinus; Venous infarction.*

INTRODUCTION

Cerebral venous sinus thrombosis (CVST) is a rare cerebrovascular disorder that accounts for approximately 0.5–1% of all strokes. Although it can affect individuals of any age, it shows a notable predilection for young adults and women of reproductive age, largely owing to the influence of pregnancy, the puerperium, oral contraceptive use, and other hormonal factors. Reported annual incidences vary from 3 to 15 cases per million in adult populations, with higher rates noted in low- and middle-income countries due to the additional contributions of dehydration, infection, and inherited thrombophilias. [1–5].

The clinical presentation of CVST is notoriously protean. Headache is the most common symptom, present in over 80% of patients, and may be the sole manifestation in a substantial subgroup. Other manifestations include seizures, papilledema, focal neurological deficits, altered mentation, and, in severe cases, coma. Because these features overlap with numerous other neurological conditions—including idiopathic intracranial hypertension, meningoencephalitis, arterial stroke, and intracranial mass lesions—neuroimaging plays a pivotal role in establishing the diagnosis. [1,3,6].

Several imaging modalities are available for the evaluation of CVST. Non-contrast computed tomography (NCCT) is often the first investigation in the emergency setting but has limited sensitivity, with reports suggesting that it can miss up to 25–30% of cases. CT venography (CTV) offers superior sensitivity and is widely used, particularly in critically ill patients, but it requires ionizing radiation and iodinated contrast. Digital subtraction angiography (DSA), once considered the reference standard, is invasive and is now reserved for selected complex cases or for endovascular intervention. [6,7,9,11].

Magnetic resonance imaging (MRI) combined with MR venography (MRV) has emerged as the imaging modality of choice for the diagnosis and follow-up of CVST. MRI directly visualizes the thrombus through evolving signal changes and concurrently demonstrates parenchymal sequelae such as venous infarcts, vasogenic and cytotoxic edema, and hemorrhagic transformation. MRV non-invasively maps the cerebral venous system using techniques such as two-dimensional time-of-flight (2D TOF), three-dimensional time-of-flight (3D TOF), phase-contrast (PC), and contrast-enhanced (CE) MRV. Each technique has unique strengths and limitations: TOF is sensitive but susceptible to flow-related artifacts; PC quantifies flow direction and velocity; and CE-MRV provides robust anatomic depiction independent of flow phenomena. [6,8,10,18,19] Despite advances in imaging technology, diagnostic challenges persist due to anatomical variants such as sinus hypoplasia, atresia, and arachnoid granulations that may simulate thrombi. A comprehensive understanding of MRV patterns and their correlation with conventional MRI findings is therefore essential for accurate interpretation. [10,17,20].

This study was undertaken to evaluate the diagnostic role of MRV in patients with clinical suspicion of CVST, to characterize the spectrum of imaging findings, to identify the most frequently involved sinuses, and to compare the relative diagnostic performance of TOF, phase-contrast, and contrast-enhanced MRV techniques.

Aim and Objectives
Aim:
To assess the role of MR venography in the diagnosis of cerebral venous sinus thrombosis.

Objectives:

- To determine the frequency and pattern of cerebral venous sinus involvement in clinically suspected patients on MRV.
- To describe the associated parenchymal MRI findings of CVST.
- To compare the diagnostic performance of 2D time-of-flight, phase-contrast, and contrast-enhanced MRV techniques.
- To correlate imaging findings with demographic and clinical risk factors.

MATERIALS AND METHODS

Study design and setting: This was a prospective, observational, hospital-based study conducted in the Department of Radiodiagnosis, Jawaharlal Nehru Medical College, in association with the Acharya Vinoba Bhave Rural Hospital, Datta Meghe Institute of Higher Education and Research (Deemed to be University), Sawangi (Meghe), Wardha, Maharashtra, India.

Study period: 1st July 2024 to 30th June 2025 (12 months).
Ethical approval: The study protocol was approved by the Institutional Ethics Committee of DMIHER (DU). Written informed consent was obtained from all participants or their legal guardians prior to imaging. Patient confidentiality was maintained throughout the study.

Sample size: A total of 50 consecutive patients fulfilling the inclusion criteria during the study period were enrolled. The sample size was calculated based on an expected prevalence of CVST among clinically suspected patients of approximately 60%, with a 95% confidence interval and absolute precision of ±13%.

Inclusion Criteria

- Patients of either sex aged 14 years and above presenting with clinical suspicion of CVST (e.g., persistent headache, seizures, focal neurological deficits, papilledema, or altered sensorium with relevant risk factors).

- Patients referred from neurology, neurosurgery, obstetrics and gynaecology, internal medicine, or emergency services.
- Patients willing and able to undergo MR imaging after informed consent.

Exclusion Criteria

- Patients with absolute contraindications to MRI (cardiac pacemaker, ferromagnetic intracranial implants, cochlear implants, or severe claustrophobia).
- Pregnant patients in the first trimester or those with known hypersensitivity to gadolinium-based contrast agents where contrast administration was indicated.
- Patients in severely uncooperative state precluding diagnostic-quality imaging.
- Patients with previously diagnosed CVST already on anticoagulation undergoing follow-up imaging only.

MRI Protocol

All examinations were performed on a 1.5-Tesla MRI scanner using a dedicated multichannel head coil. The standardized imaging protocol included the following sequences:

- Axial T1-weighted spin-echo sequence.
- Axial T2-weighted fast spin-echo sequence.
- Axial fluid-attenuated inversion recovery (FLAIR) sequence.
- Axial diffusion-weighted imaging (DWI) with apparent diffusion coefficient (ADC) maps.
- Axial gradient-recalled echo (GRE) and/or susceptibility-weighted imaging (SWI).
- 2D time-of-flight (TOF) MR venography in the axial plane with maximum-intensity-projection (MIP) reconstructions in multiple planes.
- 3D phase-contrast MR venography (velocity encoding 15–20 cm/s).
- Post-contrast T1-weighted sequences and contrast-enhanced MRV in selected cases, using gadolinium-based contrast agent at 0.1 mmol/kg.

Image Analysis

All images were independently reviewed by two consultant radiologists with at least five years of experience in neuroradiology, both blinded to the final clinical diagnosis. In cases of disagreement, consensus was reached through joint review. The following imaging parameters were systematically recorded:

- Demographic data (age, sex).
- Clinical features and identifiable risk factors.
- Site and number of sinuses involved (superior sagittal, inferior sagittal, transverse, sigmoid, straight, deep cerebral veins, cortical veins).
- Stage of thrombus on conventional MRI (acute, subacute, chronic) based on signal characteristics.
- Associated parenchymal changes: vasogenic edema, cytotoxic edema, venous infarction, hemorrhagic transformation, subarachnoid hemorrhage.
- Diagnostic performance of TOF, phase-contrast, and contrast-enhanced techniques.
- Diagnostic confidence on each technique recorded on a 3-point scale (definite, probable, equivocal).

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY). Categorical variables were expressed as frequencies and percentages, while continuous variables were summarized as mean ± standard deviation. Comparison of diagnostic performance among MRV techniques was carried out using McNemar's test where appropriate. A p-value < 0.05 was considered statistically significant.

RESULTS

Demographics

A total of 50 patients with clinical suspicion of CVST were enrolled during the study period. CVST was confirmed on imaging in 32 patients (64%), while the remaining 18 (36%) demonstrated either normal venous architecture, anatomical variants such as transverse sinus hypoplasia, or alternative diagnoses including idiopathic intracranial hypertension and meningitis. The mean age of patients with confirmed CVST was 32.4 ± 11.6 years (range: 17 to 58 years). Of these, 22 (68.7%) were female and 10 (31.3%) were male, yielding a female-to-male ratio of 2.2:1 (Table 1).

Table 1. Demographic profile of patients with confirmed CVST (n = 32).

Parameter	Value
Mean age (years)	32.4 ± 11.6
Age range (years)	17 – 58
Female, n (%)	22 (68.7%)

Male, n (%)	10 (31.3%)
Female : Male ratio	2.2 : 1

Clinical Presentation

Headache was the most common presenting symptom, observed in 28 patients (87.5%), followed by seizures in 14 (43.7%), focal neurological deficits in 9 (28.1%), altered sensorium in 7 (21.8%), papilledema in 6 (18.7%), and visual disturbances in 4 (12.5%) (Table 2). Several patients exhibited a combination of these features.

Table 2. Frequency of clinical features in patients with confirmed CVST (n = 32).

Clinical Feature	Number (n)	Percentage (%)
Headache	28	87.5
Seizures	14	43.7
Focal neurological deficit	9	28.1
Altered sensorium	7	21.8
Papilledema	6	18.7
Visual disturbance	4	12.5
Vomiting	11	34.3

Risk Factors

At least one identifiable risk factor was present in 25 (78.1%) of patients. The most common risk factor was the postpartum state, observed in 8 patients (25%), followed by oral contraceptive use in 6 (18.7%), dehydration in 5 (15.6%), inherited or acquired thrombophilia in 4 (12.5%), recent infection (paranasal sinusitis, otomastoiditis, or meningitis) in 3 (9.3%), and chronic anemia in 2 (6.2%). No identifiable risk factor was found in 7 (21.8%) patients.

Pattern of Sinus Involvement

The superior sagittal sinus was the most frequently involved, affected in 20 patients (62.5%), followed by the transverse sinus in 17 (53.1%), the sigmoid sinus in 13 (40.6%), the straight sinus in 5 (15.6%), the deep cerebral veins (internal cerebral veins/vein of Galen) in 3 (9.3%), and isolated cortical vein thrombosis in 4 (12.5%). Isolated single-sinus involvement was found in 14 patients (43.7%), while multiple sinus involvement was observed in 18 patients (56.2%) (Table 3).

Table 3. Distribution of sinus involvement in patients with confirmed CVST (n = 32).

Sinus / Vein involved	n	%
Superior sagittal sinus	20	62.5
Transverse sinus (R/L/B)	17	53.1
Sigmoid sinus	13	40.6
Straight sinus	5	15.6
Deep cerebral veins (ICV / vein of Galen)	3	9.3
Cortical veins	4	12.5
Internal jugular vein extension	3	9.3

Parenchymal Findings

Parenchymal abnormalities attributable to venous congestion were identified in 15 (46.8%) patients with CVST. Venous infarcts were seen in 11 (34.3%), of which 6 demonstrated hemorrhagic transformation. Vasogenic and cytotoxic edema without frank infarction was observed in 4 (12.5%). Subarachnoid hemorrhage was noted in 2 patients (6.2%). Thrombus signal characteristics on conventional MRI corresponded to the acute stage in 9 patients, subacute stage in 18, and chronic/partially recanalized stage in 5 patients.

Comparative Performance of MRV Techniques

2D TOF MRV demonstrated thrombus or flow void in 29 of 32 patients with confirmed CVST (sensitivity 90.6%). In 3 cases, TOF appearance was equivocal due to slow flow or sinus hypoplasia and required additional sequences for confirmation. Phase-contrast MRV identified abnormalities in 28 of 32 patients (87.5%). Contrast-enhanced MRV, performed in 22 patients with equivocal or extensive disease, accurately delineated thrombus extent in all 22 (100%) and was particularly helpful in confirming cortical vein and deep venous involvement and in distinguishing thrombosis from sinus hypoplasia (Table 4).

Table 4. Comparative diagnostic performance of MRV techniques.

Technique	True positives	Equivocal	Sensitivity (%)
2D Time-of-Flight	29 / 32	3	90.6
3D Phase-Contrast	28 / 32	4	87.5
Contrast-enhanced MRV*	22 / 22	0	100

**Performed only in selected patients (n = 22) with equivocal non-contrast findings or extensive disease.*

CASE 1:-

Young 29 years Male with sudden onset of headache and vertigo since 3 days.

Image 1:-Axial T1WI- showing left sigmoid and transverse sinus thrombosis with large filling defect and intraluminal thrombus with distended lumen shows high signal on T1.

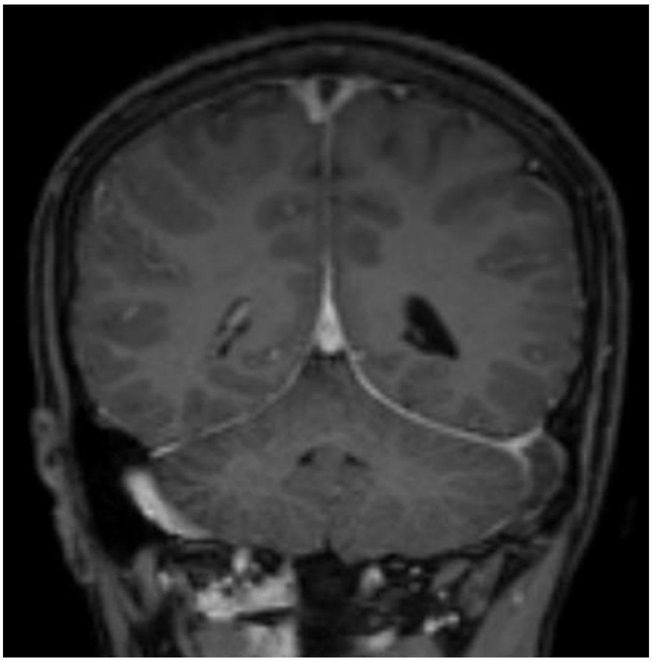

Image 2:- Coronal images shows left sigmoid and transverse sinus thrombosis with an empty delta sign on T1 post-contrast study, shows no post contrastopacificationwith intraluminal dural sinus venous thrombosis.

Image 3:-The MRV Venogram contrast -shows non-enhancement of the left straight and left transverse sinuseswith loss of opacification.

DISCUSSION

CVST remains a diagnostic challenge owing to its variable clinical manifestations and overlap with other neurological conditions. Our prospective study confirms that MR venography, particularly when combined with conventional MRI, is a highly effective and non-invasive modality for the diagnosis of CVST.

The demographic profile of our cohort, with a mean age of 32.4 years and a female predominance (68.7%), is consistent with both international and Indian literature. The International Study on Cerebral Vein and Dural Sinus Thrombosis (ISCVT) reported a similar mean age (37 years) and female predominance (74.5%). [2] Female predominance is largely attributable to the elevated risk associated with pregnancy, the puerperium, and oral contraceptive use, all of which featured prominently among the risk factors identified in our patients. [4,15]

Headache was the predominant clinical symptom, observed in 87.5% of our patients, paralleling figures from other Indian and global studies that report headache rates of 75–90%. [2,3,15] Seizures occurred in nearly 44% of our patients, a figure higher than that in some Western series and likely reflecting the relatively greater proportion of cortical and superficial sinus involvement in our population, as well as a higher burden of postpartum and infection-related thromboses.

The pattern of sinus involvement in our study mirrored published trends, with the superior sagittal sinus being the most frequently affected, followed by the transverse and sigmoid sinuses. [6,7,15,17] Multiple sinus involvement, observed in over half of our patients, is well documented in the literature and underscores the importance of comprehensive evaluation of the entire venous system rather than focal assessment.

The diagnostic strengths of MRV lie in its ability to demonstrate both the thrombus and its parenchymal sequelae in a single examination, without ionizing radiation. Conventional MRI sequences detect the thrombus through its evolving signal characteristics: in the acute phase (0–5 days), the clot is iso-intense on T1 and hypo-intense on T2 (mimicking flow void); in the subacute phase (5–15 days), it becomes hyperintense on both T1 and T2 due to methemoglobin formation; and in the chronic phase, signal characteristics vary depending on recanalization and organization. [3,6,12] SWI and GRE sequences are particularly useful in detecting blood products and isolated cortical vein thrombosis, which is otherwise easily missed. [12,13]

Among MRV techniques, 2D TOF is the most widely used owing to its short acquisition time and good background suppression. However, it is susceptible to in-plane flow saturation and may produce false-positive flow gaps in slow-flow regions or in transverse sinuses with anatomical hypoplasia. [10] In our study, 3 cases (9.3%) had equivocal TOF findings that were resolved by phase-contrast or contrast-enhanced sequences.

Phase-contrast MRV provides direction and velocity information and is less prone to saturation effects but has a lower signal-to-noise ratio and longer acquisition time. Contrast-enhanced MRV, by relying on the T1-shortening effect of intravascular gadolinium rather than on flow-related enhancement, provides superior anatomic depiction and is largely free of flow-related artifacts. In our cohort, contrast-enhanced MRV was particularly valuable in identifying cortical vein involvement, deep venous thrombosis, and in differentiating sinus hypoplasia from thrombosis. These advantages have been highlighted by Farb et al. [8] and other investigators [18,20], and have led several authors to recommend contrast-enhanced MRV as the technique of choice when the diagnosis is uncertain.

The distinction between sinus hypoplasia/atresia and thrombosis is one of the most common diagnostic pitfalls. A small or absent transverse sinus on MRV may be misinterpreted as thrombosis. [10,17] Helpful clues include the absence of associated parenchymal abnormalities, lack of T1/T2 signal change in the sinus on conventional sequences, concordance with bony groove size on co-registered images, and homogeneous opacification on contrast-enhanced MRV without filling defects.

Our findings reaffirm that MRV should be tailored to the clinical question. In acute presentations with high clinical suspicion, the combination of conventional MRI (including SWI), 2D TOF, and contrast-enhanced MRV provides the highest diagnostic confidence. In follow-up of treated patients, non-contrast techniques may suffice for assessing recanalization.

Limitations

This study has several limitations. First, it was conducted at a single tertiary care centre over a one-year period, with a modest sample size of 50 patients, which may limit generalizability. Second, DSA was not performed for confirmation in any patient because of its invasive nature, and final diagnosis was based on consensus imaging interpretation supplemented by clinical follow-up. Third, inter-observer agreement was reported descriptively rather than quantified by formal kappa statistics. Finally, long-term follow-up imaging to assess recanalization rates was beyond the scope of this study and may form the basis for future work.

CONCLUSION

MR venography, when combined with conventional MRI sequences including SWI/GRE, is a highly effective, non-invasive, and radiation-free imaging modality for the diagnosis of cerebral venous sinus thrombosis. The superior sagittal sinus is the most frequently involved sinus, and multiple sinus involvement is common. Contrast-enhanced MRV demonstrates superior diagnostic confidence over time-of-flight and phase-contrast techniques, particularly in equivocal cases and in evaluating cortical and deep venous involvement. We recommend that MRV, including a contrast-enhanced sequence in selected cases, be incorporated as a first-line investigation in patients with clinical suspicion of CVST to enable prompt diagnosis and timely initiation of anticoagulation.

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Nil.

Conflict of Interest
None declared.

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