Beyond The Grayscale: Re-evaluating The Prognostic Value Of CT Density In Cerebral Venous Thrombosis (Abstract ID: 591)

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Background: Cerebral venous thrombosis (CVT) is a rare stroke subtype resulting from thrombus formation in the Dural venous sinuses. Non-enhanced computed tomography (NECT) is commonly used as an initial imaging modality due to its wide availability and speed, although its diagnostic accuracy remains limited (sensitivity 68% and specificity 52%). This study aimed to evaluate whether serial CT density measurements could serve as a simple tool for monitoring thrombus evolution over time.

AIM

To evaluate longitudinal changes in CT density and the Hounsfield-to-Hematocrit (H:H) ratio within the affected cerebral venous sinuses in patients with cerebral venous thrombosis (CVT).

To determine whether their temporal patterns differ based on recanalization outcomes.

MATERIALS AND METHODS

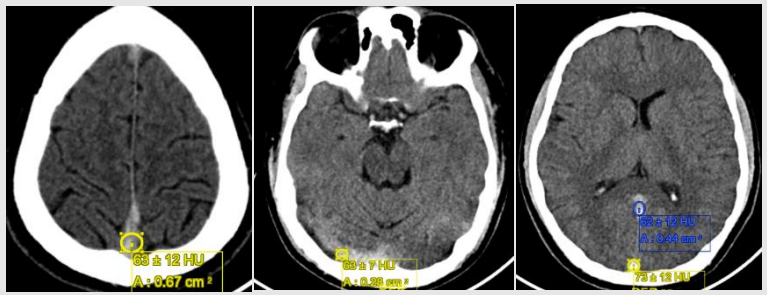
This was a prospective observational study conducted at the Department of Neurology, National Institute of Mental Health and Neurosciences (NIMHANS),between March 2023 to May 2025.

Inclusion Criteria

- Age > 18 years.
- Both male and female patients.
- CVT confirmed by clinical and imaging studies within two weeks of symptom onset.
- Availability of at least two serial non-contrast CT (NCCT) scans during the hospital stay or initial evaluation.

Exclusion Criteria

- Patients without serial imaging at baseline or during follow-up (6 months to 1 year).
- Contraindication to CT imaging.
- Patients with chronic CVT.



TREATMENT PROTOCOL- All the patients in this study were treated with standard anticoagulation, consisting of unfractionated heparin (UFH) 5000 IU subcutaneously four times daily for 7–10 days, followed by oral acenocoumarol with a tailored loading regimen (3 mg on day 7, 2 mg on day 8, and 1 mg on day 9), with subsequent dose adjustments made to maintain an INR between 1.5 and 2.

IMAGING AND ANALYSIS

Plain CT scans (16/128-slice: GE Optima, GE Bright Speed, Siemens) were used. Sinus density was measured using ROI in the involved venous sinuses (superior sagittal, bilateral transverse, straight, and others). Mean attenuation was recorded in Hounsfield Units (HU) and normalized with the Hounsfield-to-hematocrit (H:H) ratio to account for hematocrit variation.Follow-up imaging included non-contrast CT at 3 months for puerperal CVT cases and at 6 months for non-puerperal cases, along with complete blood count to calculate the H:H ratio. CT venography/MR venography was performed at 6 months (puerperal) and 12 months (non-puerperal) to assess venous sinus recanalisation, which was categorized as partial or complete. Data were analyzed using SPSS v29 and R. Repeated-measures ANOVA was applied for normally distributed variables (CT density, H:H ratio), and the Friedman test for non-normal data. A stringent significance level of $p \leq 0.001$ was used to minimize Type I error across multiple time-point assessments

RESULTS

A total of 85 patients meeting the inclusion criteria were initially enrolled. Four patients died during hospitalization, and 35 were lost to follow-up at the 3–6-month interval. Thus, 46 patients were included in the final analysis. Among these, 26 were males (56.5%) and 20 were females (43.5%), with a median age of 33 years (IQR: 24.3–40; range: 18–50). Headache was the most common presenting symptom, observed in all patients (100%), followed by seizures in 63% and encephalopathy in 52.2%.

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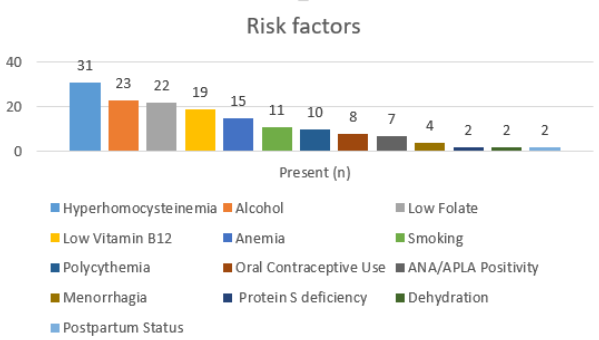
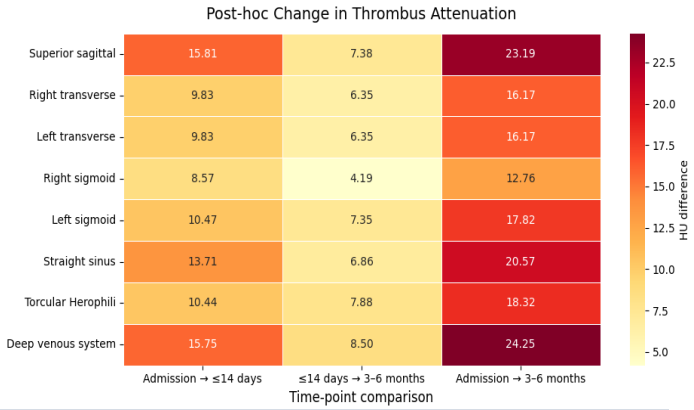
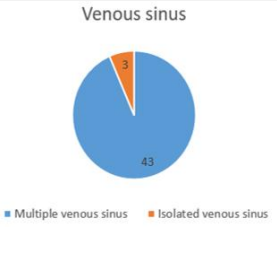


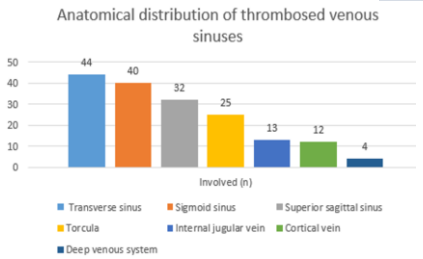
Venous Sinus Density	Admission → ≤14 days CT Density	≤14 days → 3–6 months CT Density	Admission → 3–6 months CT Density
Superior sagittal	15.81 HU (p < 0.001)	7.38 HU (p = 0.0007)	23.19 HU (p < 0.001)
Right transverse	9.83 HU (p < 0.001)	6.35 HU (p = 0.000761)	16.17 HU (p < 0.001))
Left transverse	9.83 HU (p < 0.001)	6.35 HU (p = 0.000761)	16.17 HU (p < 0.001)
Right sigmoid	8.57 HU (p = 0.00994)	4.19 HU (p = 0.743)	12.76 HU (p = 0.0087)
Left sigmoid	10.47 HU (p = 0.013)	7.35 HU (p = 0.102)	17.82 HU (p < 0.001)
Straight sinus	13.71 HU (p = 0.003)	6.86 HU (p = 0.116)	20.57 HU (p < 0.001)
Torcular Herophili	10.44 HU (p < 0.001)	7.88 HU (p = 0.0578)	18.32 HU (p < 0.001)



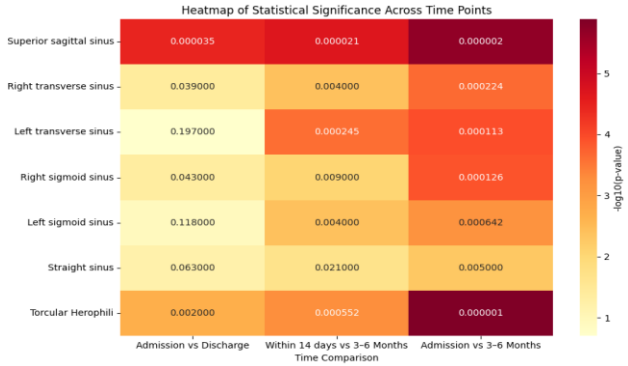
Among males (n = 26), hyperhomocysteinemia (92.3%, n = 24) and alcohol consumption (84.6%, n = 22) were most common, whereas among females (n = 20), anemia (65.0%, n = 13) was predominant, followed by hyperhomocysteinemia (35.0%, n = 7).

Significant reductions in thrombus density were observed in the superior sagittal, straight, left sigmoid, bilateral transverse sinuses, and torcula, while changes in the right sigmoid, deep venous system, and cortical vein did not reach the ≤0.001 threshold. Post hoc pairwise comparisons of venous sinus density across time points showed significant CT density reductions between admission and 3–6 months in major sinuses, reflecting ongoing thrombus resolution. Early substantial changes were observed only in the superior sagittal sinus, transverse sinuses, and torcula.





Venous Sinus H:H Ratio	Admission Median [IQR] H:H Ratio	≤14 days Median [IQR] H:H Ratio	3–6 months Median [IQR] H:H Ratio	p-value
Superior sagittal	1.57 [1.27–2.08]	1.31 [0.97–1.66]	0.90 [0.80–1.04]	<0.001
Right transverse	1.42 [1.19–1.72]	1.25 [1.11–1.47]	0.99 [0.87–1.13]	<0.001
Left transverse	1.41 [1.18–1.62]	1.14 [1.02–1.53]	0.94 [0.85–1.09]	<0.001
Right sigmoid	1.45 [1.27–1.70]	1.33 [1.13–1.51]	1.10 [0.92–1.30]	<0.001
Left sigmoid	1.43 [1.31–1.77]	1.29 [1.09–1.46]	1.06 [0.84–1.16]	0.002
Straight sinus	1.39 [1.21–1.56]	1.10 [0.98–1.17]	0.95 [0.75–1.02]	0.002



Multiple sinus involvement was observed in 93.5% (n = 43), while isolated sinus involvement was noted in 6.5% (n = 3). The transverse sinuses were the most frequently involved sites (95.7%), followed by the sigmoid sinuses (87.0%), superior sagittal sinus (69.6%), torcula (54.3%), internal jugular vein (28.3%), cortical veins (26.1%), straight sinus (15.2%), and deep venous system (8.7%)

H:H ratio declined significantly in most venous sinuses over time ($p < 0.001$), with the strongest and most consistent reductions in the superior sagittal and torcular sinuses. Sigmoid sinuses showed delayed but significant changes, while the straight sinus demonstrated only a non significant downward trend. Post hoc pairwise comparisons across time points showed that most sinuses, except for the straight sinus, exhibited a statistically significant reduction in the hemoglobin-to-hematocrit ratio over time ($p < 0.001$), with the greatest changes observed between admission and the 3–6-month follow-up. The contrast between the CT density HU-based trends and the H: H ratio findings emphasizes the influence of hematocrit on CT attenuation values

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In the present cohort, follow-up MRI demonstrated complete recanalisation in 56.5% and partial recanalisation in 43.5% of patients. Our cohort showed that a notably lower thrombus burden (i.e., fewer than four sinuses involved) was significantly associated with complete recanalisation, reinforcing the importance of clot extent as a prognostic marker.

Sinus	Recanalization	Time point						Between Groups (p)	Within Groups (p)	Interaction (p)
		Admission H:H Ratio	Admission CT Density	Within 14 days H:H ratio	Within 14 days CT density	3–6 Months H:H ratio	3–6 Months CT density	Recanalization	Time	Recanalization with time
Superior sagittal sinus	Partial	1.38 [1.22–1.53]	60 [53–65]	1.17 [0.96–1.38]	41 [37–47]	0.93 [0.86–0.98]	37 [35–44]	0.173	< 0.001	0.199
	Near-complete	1.86 [1.445–2.12]	62 [56.5–71]	1.45 [1.01–1.675]	49 [45–52]	0.95 [0.775–1.075]	39 [37.5–45.5]			
Right transverse sinus	Partial	1.415 [1.175–1.695]	54.5 [49–59.3]	1.245 [1.125–1.47]	48 [44.5–49]	1.02 [0.943–1.17]	45.5 [42–46]	0.878	< 0.001	0.369
	Near-complete	1.42 [1.215–1.81]	57 [52.5–59]	1.36 [1.03–1.705]	50 [44.5–58.5]	0.87 [0.775–0.98]	36 [34.5–43.5]			
Left transverse sinus	Partial	1.545 [1.265–2.02]	63 [57.3–65.8]	1.15 [1.058–1.4]	46 [45–48.8]	0.95 [0.94–1.06]	39.5 [37–45.8]	0.353	< 0.001	0.061
	Near-complete	1.39 [1.07–1.52]	53 [50–57]	1.05 [1.009–1.55]	48 [44–52]	0.92 [0.84–1.10]	39 [38–46]			
Straight sinus	Partial	1.30 [1.255–1.345]	56 [52–60]	1.015 [0.968–1.063]	43.5 [41.3–45.8]	0.885 [0.838–0.933]	36.5 [36.3–36.8]	0.461	< 0.001	0.930
	Near-complete	1.48 [1.22–1.64]	64 [59–73]	1.10 [1.04–1.22]	51 [45–54]	0.96 [0.80–1.06]	43 [42–45]			
Right sigmoid sinus	Partial	1.52 [1.283–1.84]	59 [51.8–63.5]	1.315 [1.153–1.395]	47.5 [44–53.5]	1.15 [1.005–1.323]	50.5 [45.3–52.5]	0.285	< 0.001	0.203
	Near-complete	1.45 [1.20–1.625]	53 [52–60]	1.42 [1.015–1.56]	48 [45.5–52.5]	0.76 [0.74–1.117]	44 [33–48]			
Left sigmoid sinus	Partial	1.71 [1.53–2.205]	69 [59–77]	1.40 [1.205–1.53]	49 [44.5–51]	1.06 [0.945–1.25]	45 [42–49]	0.131	< 0.001	0.314
	Near-complete	1.405 [1.235–1.543]	61.5 [50.5–69]	1.235 [1.06–1.358]	50.5 [45.5–58]	0.995 [0.825–1.158]	46 [40.8–48.8]			
Torcular Herophili	Partial	1.47 [1.29–1.685]	62 [59.5–69]	1.28 [1.075–1.675]	51 [45–54.5]	1.03 [0.92–1.145]	39 [37–50]	0.625	< 0.001	0.927
	Near-complete	1.43 [1.17–1.78]	59.5 [56–62.5]	1.20 [1.05–1.42]	50 [49–53]	0.98 [0.92–1.11]	46.5 [43.3–49.8]			

Significant reduction in attenuation across all sinuses over time (<0.001). while near-complete recanalization groups often began with higher median H: H ratios, the gap between groups narrowed over time, and by 3–6 months, most values converged toward a similar range of approximately 0.9 to 1.0. Overall attenuation of ratios did not differ substantially between patients with partial and near-complete recanalization. CT Density and H:H Ratio declined in a comparable pattern over time in both partial and near-complete recanalization groups.

At one year, most patients demonstrated favorable recovery. Headache resolved in 71.7%, papilledema in 95.7%, and cognitive performance improved, with over half (54.5%) achieving normal scores. Functional outcomes were also favorable, with 95.6% attaining mRS 0–2. Overall, 89.1% had one or no residual impairment, underscoring a predominantly favorable recovery profile across neurological, functional, and cognitive domains

CONCLUSION

A time-dependent decline in thrombus density was observed across multiple venous sinuses, although the pattern and rate of reduction varied across different time intervals and sinus locations. These variations suggest that anatomical factors and the inherent complexity of venous recanalization may influence thrombus resolution. The most consistent decrease was seen between admission and 3–6 months across nearly all sinuses.

The contrast between HU-based CT density trends and H:H ratio findings highlights the influence of hematocrit on attenuation values, as many patients were treated for anemia or polycythemia during hospitalization, potentially affecting early HU readings. In this context, the H: H ratio appears to be a more reliable and stable marker of thrombus evolution, less affected by transient hematocrit fluctuations.

Within recanalization subgroups, both Hounsfield Unit (HU) values and H: H ratios significantly declined over time across all venous sinuses. However, neither the absolute CT density values , H:H ratio nor the rate of their decline significantly influenced the degree of recanalization.

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