Original Article

Evaluation of the mean Venous Hounsfield Value in Non-Contrast CT scans of the Brains of Patients with Cerebral Venous Thrombosis Compared to Normal People

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Received: 14 May, 2025; Accepted: 13 July, 2025

DOI: 10.22037/nbm.v13i4.48366

Abstract

Background: Cerebral Venous Sinus Thrombosis (CVST) is a significant cause of stroke associated with elevated morbidity and mortality rates, presenting diagnostic challenges. Non-contrast computed tomography (NCCT) is among the initial imaging modalities utilized for patients presenting with neurological symptoms or those who have experienced trauma. Research indicates a potential association between venous Hounsfield (HU) values in brain NCCT and CVST; however, the existing studies in this regard remain limited. This study investigates the relationship between the venous HU value from NCCT of the brain and CVST.

Materials and Methods: This retrospective case-control study was conducted on patients referred to Ali Ibn Abi Taleb Hospital (Rafsanjan, Iran) from the start to the end of 2024. Patients with CVST who were admitted to the neurological emergency department with suspected clinical symptoms were studied as the case group (30 patients), and normal individuals (30 people) were studied as the control group. Patient information, including age, sex, involved vein, and final opinion of radiologists regarding venous involvement, was recorded. The significance level was considered less than 0.05.

Results: NCCT images were compared between the groups. There was no statistically significant difference between the two groups in terms of age, sex, and smoking (P-values > 0.05). The most common site of thrombosis was the superior sagittal sinus (53.3%). The mean attenuation in the CVST group was 63.67 ± 1.9 HU, and in the control group it was 52.03 ± 1.25 HU (P-value < 0.01). Hemoglobin levels were within normal limits in both groups. Still, they were significantly lower in the CVST group (P-value: 0.014), and with a one-unit increase in hemoglobin level, the probability of CVST increased by about 33.2% (95% CI: 1.050–1.690). Frequency of OCP use, previous history of abortion, and previous history of thrombosis did not differ statistically significantly between the groups (all P-values > 0.05).

Conclusion: Higher attenuation in the NCCT of these patients may be used as a diagnostic criterion in the clinic.

Keywords: Cerebral venous thrombosis, Stroke, Non-contrast CT scan, Hounsfield

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Please cite this article as: Talebi Farahani M, Rahimi MK, Haghighat S, Gudarzi M. Phylogenetic Groups and Antimicrobial Resistance among Uropathogenic *Escherichia coli* Isolates from Hospitalized Patients in Tehran. Novel Biomed. 2025;13(4):203-208.

Introduction

Cerebral venous sinus thrombosis (CVST) accounts for 0.5% of strokes, with an incidence of 3 to 4 cases per million in the adult population[1]. CVST may manifest with various nonspecific symptoms, including headaches, seizures, and focal neurological deficits. Consequently, CVST is often not identified during its initial phases[2,3]. CVST is recognized as a contributing factor to stroke in children and infants, with an estimated mortality rate ranging from 8% to 19%. Various imaging modalities exist for the diagnosis of CVST and other neurological disorders[4]. Non-contrast computed tomography (NCCT) is the predominant imaging modality for patients exhibiting nonspecific neurological symptoms upon arrival at the emergency department. The primary characteristic of CVST is the heightened density of the venous sinus, commonly referred to as the rope sign. The early diagnosis of CVST is challenging and necessitates the application of additional assessment methods[5-7].

Prior research has examined the diagnostic accuracy of certain NCCT imaging markers for the early detection of CVST, including the Hounsfield Unit (HU) value. However, investigations in this domain remain limited, necessitating further studies to assess the Hounsfield value in CVST patients using NCCT [8-10]. The objective of this study was to examine the mean venous Hounsfield value on brain NCCT in patients with CVST in comparison to normal subjects.

Methods

This case-control study assessed patients with CVST admitted to the neurological emergency department referred to Ali Ibn Abi Taleb Hospital (Rafsanjan, Iran) in 2024, constituting the case group, alongside a control group of normal subjects matched in number.

The inclusion criteria were having a non-contrast CT scan of the brain and involvement with neurological symptoms[11]. The exclusion criteria were having anemia, not having a CT scan, and incomplete patient record information.

All CT scans were obtained using the Somatom Sensation 40 open system (Siemens, Erlangen, Germany). The scanning settings employed were: 120 kV, 220 mA, with a slice thickness of 3 mm below the tentorium, and 120 kV, 260 mA, with a slice thickness of 4.8 mm above the tentorium.

Two experienced neuroradiologists assessed NCCT scans for both direct and indirect indicators of CVST. Observers were unaware of clinical data and patient identification. Readings were randomized, and standardized assessment forms were employed to ensure a systematic evaluation of the following structures: superior sagittal sinus, straight sinus, inferior sagittal sinus, right and left transverse sinuses, and right and left sigmoid sinuses. The right and left internal cerebral veins, the vein of Galen, right and left basal veins of Rosenthal, right and left thalamostriate veins, and cortical veins were analyzed. Attenuation in the thrombosed venous sinus was quantified. If no venous structure was identified as thrombus, the mean attenuation of up to three venous sinuses, distinguishable from the surrounding brain parenchyma, was documented. The assessment included the presence of parenchymal hemorrhage or edema.

Data on age, gender, smoking, underlying disease, oral contraceptive use, hemoglobin level, thrombosis history, and recurrent abortion were evaluated and recorded based on patients' data.

Statistical analysis: SPSS version 24 software was utilized. Descriptive statistics were presented as "mean ± standard deviation" and "frequency (percentage)." The normality of the frequency distribution was assessed using the Kolmogorov–Smirnov test. The chi-square and Fisher tests were employed for the comparison of qualitative variables, while the t-test was utilized for quantitative variables. The logistic regression model was used to examine the effect of additional variables, with results presented as odds ratios (ORs) accompanied by 95% confidence intervals (CIs). All p-values were reported as two-tailed, with a significance level set at less than 0.05.

Ethical consideration: This study has been approved by the Ethics Committee of Rafsanjan University of Medical Sciences (IR.RUMS.REC.1403.150).

Results

Thirty patients were assessed as the case group, and thirty healthy participants were evaluated as the control group. The basic data of both groups are shown in Table 1. There were no significant differences between case and control groups about age, gender, and smoking (all P-values>0.05).

Table 2 demonstrates the distribution of thrombosis sites. The most common site was the superior sagittal sinus, which accounts for 53.3% of cases. There was a significant difference between the two groups regarding HU values. The mean HU value in the case group was 63.67±1.9 and in the control group was 52.03±1.25 (p<0.001, based on T-test).

Table 1. Basic data of case and control groups.

		group								
		Case				Control				
		Mean	Standard Deviation	Count	Column N %	Mean	Standard Deviation	Count	Column N %	P-value
Age		37.30	4.35	-	-	38.90	5.29	-	-	0.206*
Gender	male		-	6	20.0		-	8	26.7	0.381**
	female			24	80.0			22	73.3	
Smoking	Yes		-	6	20.0		-	5	16.7	0.45**
	No			24	80.0			25	83.3	
Underlying disease	Yes		-	0	0.0		-	0	0.0	—
	No			30	100			30	100.0	

*P-value based on T-test, **P-value based on Chi-Square and Fisher Exact test.

Table 3 shows a comparison between the case and control groups on the variables of oral contraceptive pill (OCP) use, hemoglobin level, history of thrombosis, and recurrent miscarriage. The mean hemoglobin level in the case group was 15.10±2.40 g/dL, while the mean hemoglobin level in the control group was 13.63±2.09 g/dL. This difference is statistically significant (p=0.014), indicating that hemoglobin levels are significantly higher in patients with CVST.

Logistic regression was employed to analyze the relationship between hemoglobin levels and the likelihood of CVST in comparison to the control group. The findings indicated a significant association between hemoglobin level and case/control status (β coefficient=0.287, standard error=0.121, Wald=5.591, p=0.018). The odds ratio for each unit increase in hemoglobin level was 1.332 (95% CI: 1.050–1.690). A one-unit increase in hemoglobin level corresponds to an approximate 33.2% increase in the likelihood of being classified in the case group relative to the control group. In conclusion, hemoglobin level may serve as a potential risk factor for the occurrence of CVST. Logistic regression analysis revealed no statistically significant relationship between Hounsfield value and the occurrence of CVST. The regression coefficient for Hounsfield is 6.732, accompanied by a notably high standard error of 1071.867, which suggests instability and imprecision in the coefficient estimate. The Wald statistic is 0.000, and the p-value is 0.995, indicating that this variable does not exert a statistically significant effect. The odds ratio (OR=839.046) is substantial and lacks interpretability, with an incomplete or absent

Table 2. Distribution of thrombosis sites.

		Case group	
		Count	Column N %
Thrombosis location	Superior sagittal sinus	16	53.3
	Straight sinus	1	3.3
	Inferior sagittal sinus	2	6.7
	Sinus sigmoid	2	6.7
	Transverse sinus	3	10.0
	Combined	6	20.0

Table 3. Results of data on OCP use, hemoglobin level, thrombosis history, and recurrent abortion.

		Group								
		Case				Control				
		Count	Column N %	Mean	Standard Deviation	Count	Column N %	Mean	Standard Deviation	P-value**
OCP	Yes	9	30.0		-	3	10.0		-	0.052
	No	21	70.0			27	90.0			
Hemoglobin level				15.10	2.40		-	13.63	2.09	0.014
Thrombosis history	Yes	1	3.3		-	0	0.0		-	0.5
	No	29	96.7			30	100.0			
Recurrent abortion	Yes	2	6.7		-	0	0.0		-	0.492
	No	28	93.3			30	100.00			

**P-value based on Chi-Square and Fisher Exact test.

Table 4. Assessment of the correlation between hemoglobin level and HU value with CVST based on logistic regression.

	B	SE.	Wald	df	P value	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
HU value	6.732	1071.867	0.000	1	0.995	839.046	0.000	0.0
Hemoglobin level	0.287	0.121	5.591	1	0.018	1.332	1.050	1.690

confidence interval (Upper=0.0). This suggests that there is insufficient data or potential issues within the model, including collinearity, sparsity, or an inadequate sample size. The intercept exhibits an irrational and statistically insignificant value (β=-386.749, SE=61662.733, p=0.995) (Table 4).

Discussion

Intraluminal thrombosis typically presents as a hyperattenuating lesion on NCCT conducted during the acute phase of the condition. Increased attenuation, typically related to a reduction in water content within the clot and a rise in the concentration of red blood cells and hemoglobin, is referred to as the cord sign or dense triangle sign[12,13]. The sensitivity of this finding has been reported to range from 63% to 73% across various studies. A quantitative measurement of attenuation is thought to identify a moderate increase in the mean density of the sinus[14]. This study compared NCCT images of 30 patients with CVST to those of 30 healthy controls, focusing on HU measurements. The two groups did not exhibit statistically significant differences regarding age, sex, and smoking status. No underlying disease was present in either group. The superior sagittal sinus was the most prevalent site of thrombosis in the patient group, accounting for 53.3% of cases. The mean attenuation value in the CVST group was 63.67 ± 1.9, while in the control group, it was 52.03 ± 1.25, indicating a significant difference in favor of the CVST group. The hemoglobin levels in both groups were within the normal range; however, the levels were significantly higher in the CVST group compared to the control group.

Furthermore, a one-unit increase in hemoglobin level was associated with an approximate 33.2% increase in the probability of CVST. The use of OCP, prior history of abortion, and prior history of thrombosis did not show statistically significant differences between the groups. The cut-off of 57.5 HU differentiated thrombosis with 100% sensitivity and specificity.

Canakci et al. conducted a study involving 41 patients with cerebral thrombosis (CVT) and 41 control subjects, finding no significant differences in age, sex, hemoglobin, and hematocrit (Hct) values between the two groups. The mean HU value in the CVT group was 75±7, while in the control group it was 52±6 ($p<0.001$)[9]. Our study revealed a statistically significant difference in hemoglobin levels between the two groups, with higher levels observed in the patient group. The mean HU for the case group was 63.67±1.9, while for the control group it was 52.03±1.25.

Avsenik et al. evaluated the sensitivity and specificity of NCCT for the diagnosis of CVST. Thirteen patients were confirmed to have CVST. The sensitivity and specificity of NCCT for detecting CVST were 100% and 83%, respectively, with a kappa value of 0.72. The attenuation values exhibited significant differences between CVST patients and controls[6]. The present study observed a significant difference in attenuation between patients with CVST and healthy subjects, with higher values in the CVST group. This finding aligns with the significant difference in HU reported between the two groups in both studies. The findings from these two studies indicate that attenuation-based assessment of CVST in NCCT images is an appropriate diagnostic approach for clinical use. It is important to acknowledge that the majority of studies, including the current one, have not been conducted on a large population, representing a common limitation in research.

The limited sample size of studies in this field is attributed to the prevalence of CVST. CVST is an uncommon form of stroke marked by the development of blood clots within the dural venous sinuses[15]. The prevalence is approximately 3 to 4 cases per million individuals[16]. Consequently, the majority of studies exhibit limited sample sizes.

Shayganfar et al. investigated the importance of NCCT in diagnosing CVST. The mean attenuation in patients was 66.95 ± 10.63 HU, while in the control group it was 52.51±2.92 HU, indicating a significant difference between the two groups. The mean hemoglobin to hematocrit (H:H) ratio in patients was 1.78±0.40, while in controls it was 1.46±0.28. An H:H ratio exceeding 1.42 demonstrated optimal performance, achieving a sensitivity of 94.3% and a specificity of 54.3% for the diagnosis of CVST[17]. Research indicated that assessing attenuation in the sinus and normalizing this measurement to hematocrit (H:H) may effectively identify CVST in CT imaging. Some small studies have assessed sinus venous attenuation, demonstrating that the H:H ratio exhibits good sensitivity and is beneficial for diagnosing CVST[18-20]. This study did not examine the H:H ratio; however, a statistically significant difference was noted between the hemoglobin levels of the CVST group and the control group, despite both groups having levels within the normal range. This suggests the potential for evaluating hemoglobin status and its significance in diagnosing CVST; however, research in this regard is limited, necessitating further investigation.

Buyck et al. conducted a study examining the additional diagnostic utility of semiquantitative imaging markers on NCCT scans in cases of cerebral venous thrombosis. The attenuation measurement yielded an area under the curve (AUC) of 0.78. Following hematocrit adjustment, the AUC was maintained at 0.78. The analysis of attenuation ratios between affected and healthy sinuses yielded an area under the curve (AUC) of 0.83. The incorporation of this imaging marker notably enhanced diagnostic accuracy[21]. The correlation between hemoglobin and hematocrit suggests that hemoglobin levels may enhance the diagnostic capability of CVST in NCCT. However, further investigation is necessary, as the current study has confirmed the association of sinus attenuation with hemoglobin in patients with CVST.

A study by Della Vega Manz et al. investigated the application of attenuation based on HU and hematocrit values for diagnosing acute venous sinus thrombosis using unenhanced brain CT in a pediatric population. A statistically significant difference in sinus attenuation and HU:Hct ratio was noted between thrombosed sinuses (66.2±5.3 HU, 1.96±0.4) and nonthrombosed sinuses (47.2±4.5 HU, 1.38±0.25) within the patient group. A statistically significant difference was observed in the attenuation of thrombosed sinuses between the patient group and the control group[22]. A significant difference in hemoglobin levels and sinus attenuation was observed between the two groups in the current study. The results of these two studies were comparable. This highlights the diagnostic significance of sinus attenuation and hemoglobin levels in patients with CVST.

Tayyibi et al. found that the mean attenuation in thrombosed sinuses was 65.8, while in nonthrombosed sinuses it was 44.9, indicating a significant difference. The absolute sinus attenuation cutoff of 61 HU yielded a sensitivity of 82%, specificity of 100%, and accuracy of 92%[10]. The current study found that the mean attenuation in subjects with CVST was 63.67 HU, while the control group exhibited a mean of 52.03 HU. These findings are consistent with two previous studies on CVST patients, suggesting the potential diagnostic value of this criterion for identifying patients with CVST.

Conclusion

The mean venous Hounsfield score in brain NCCT for patients CVST is significantly elevated compared to that of normal subjects. The increased attenuation observed in the NCCT of these patients may serve as a diagnostic criterion in clinical settings. Our findings indicate that the blood hemoglobin levels in these patients were significantly elevated compared to those of normal subjects. The application of NCCT may serve as an effective method for diagnosing CVST, utilizing the Hounsfield unit as a criterion.

Acknowledgment

None.

Funding

None.

Conflict of interest

The authors further declare that they have no conflict of interest.

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