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Original Article

Diagnostic efficacy of susceptibility weighted imaging for the identification of cerebral venous thrombosis

Dr Chandana Udayakumar[1], Dr Kiran Kumar B.M[2], Dr Nithyashree B[3], Dr Shruti V Dixit[4]

[1,2,3] Assistant professor, Department of Radiodiagnosis, Dr Chandramma Dayananda Sagar Institute of Medical Education and Research, Harohalli, Bengaluru south-562112.
[4] Senior Resident, Department of Radiodiagnosis, Dr Chandramma Dayananda Sagar Institute of Medical Education and Research, Harohalli, Bengaluru south-562112.

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Corresponding Author:

Dr Chandana Udayakumar
Assistant professor, Department of Radiodiagnosis, Dr Chandramma Dayananda Sagar Institute of Medical Education and Research, Harohalli, Bengaluru south-562112.

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ABSTRACT

Introduction: Cerebral venous thrombosis (CVT) constitutes 0.5% of all strokes. it includes thrombosis of cerebral cortical veins and dural sinuses. Phase contrast Magnetic Resonance Venography (MRV) of the brain is the gold standard for the diagnosis of cerebral venous thrombosis (CVT). Susceptibilityweighted imaging (SWI)is a novel MRI sequence characterized by exceptionally high spatial resolution. It is a 3d gradient echo(gre) magnetic resonance (MR) method employed to enhance cerebrovascular diagnosis particularly due to its capacity to identify microbleeds and better visibility of the veins owing to their increased sensitivity toVariation in magnetic susceptibility. Our study was aimed to know the diagnostic performance of SWI in detecting CVT compared to MRV and to facilitate early diagnosis of CVT where MRV not feasible.

Material and Methods: A prospectively study, included patients presenting with clinical symptoms of CVT who underwent MRI (1.5T) brain with MRV. We determined the sensitivity, specificity, predictive value, accuracy, degree of agreement between SWI and MRV in detecting CVT.

Results: Out of 30 cases, 21 were females. Majority of patients presented with headache (100%) and CVT was diagnosed in 18 cases. The overall diagnostic accuracy of SWI sequence was 79.61% and that of MRV was 89.45%. Sensitivity of SWI versus MRV was 61.22% Vs 92.10%; Specificity 94.33% Vs 100%; Positive predictive value 91.65% vs 100%; Negative predictive value 69.33% vs 88.64% respectively. 95% confidence interval was observed for the specificity and positive predictive value of the SWI test. There exists good degree of agreement between both imaging modalities with 98% accuracy to detect cortical vein thrombosis by SWI.

Conclusion: MRV continues to be the gold standard for diagnosing CVT. A degree of consensus exists between MRV and SW1 sequences. Both sequences (MRV and SW1 sequence) exhibit significant concordance in cases of superior sagittal sinus thrombosis and straight sinus thrombosis. SWI is the benchmark for diagnosing isolated superficial cortical vein thrombosis.
Conventional MRI with SWI would assist in confirming CVT in most instances when MRV is impractical.

Keywords*: Venous Thrombosis, Gradient Echo Image, Magnetic Resonance Venography, Susceptibility-weighted imaging.*

INTRODUCTION

Cerebral venous thrombosis (CVT) constitutes 0.5% of all strokes. It includes thrombosis of cerebral cortical veins and dural sinuses. (1)

The clinical manifestation of cerebral venous thrombosis (CVT) is variable and encompasses headache, seizures, focal motor deficits, elevated intracranial pressure, and coma. (2) In the majority of instances, headache is the primary manifestation.

The diagnosis of CVT is delayed because of its diverse presentation and risk determinants. Consequently, a heightened index of suspicion for CVT is warranted for timely diagnosis and intervention. Phase contrast Magnetic Resonance Venography (MRV) of the brain is the gold standard for the diagnosis of cerebral venous thrombosis (CVT). (3) Susceptibility-weighted imaging (SWI) is a novel MRI sequence characterized by exceptionally high spatial resolution. It is a 3D gradient echo (GRE) magnetic resonance (MR) method employed to enhance cerebrovascular diagnosis, (4) particularly due to its capacity to identify microbleeds and better visibility of the veins owing to their increased sensitivity to variation in magnetic susceptibility. SWI has been proven to give clinically pertinent information that is complementary to conventional MR imaging regimens employed in the assessment of several neurological diseases. Furthermore, SWI is also effective in identifying isolated cortical vein thrombosis. (5) Evaluation of cerebral venous thrombosis by susceptibility-weighted imaging sequence of the brain has limited comparisons between it and MRV in the literature. In this study, we aim to evaluate the diagnostic efficacy of SWI with the efficacy of MRV brain in identifying CVT.

MATERIAL AND METHODS

Study design: A prospective study conducted from June 2025 to December 2025. The study included patients presenting with headache in the Department of General Medicine, CDSIMER, DSU, with clinical suspicion of CVT, in whom MRI brain sequences with SWI and phase contrast MRV brain were performed in the Department of Radiology. Brain MRI images were acquired using a 1.5T Philips Achieva MRI scanner. The scanner utilized various imaging sequences, including T1-weighted images, T2-weighted images, FLAIR sequences, diffusion-weighted sequences, SWI sequences, and phase contrast MRV. SWI is an MRI technique that capitalizes on the magnetic susceptibility differences among blood, calcium, and iron, thereby facilitating novel sources of MR contrast.

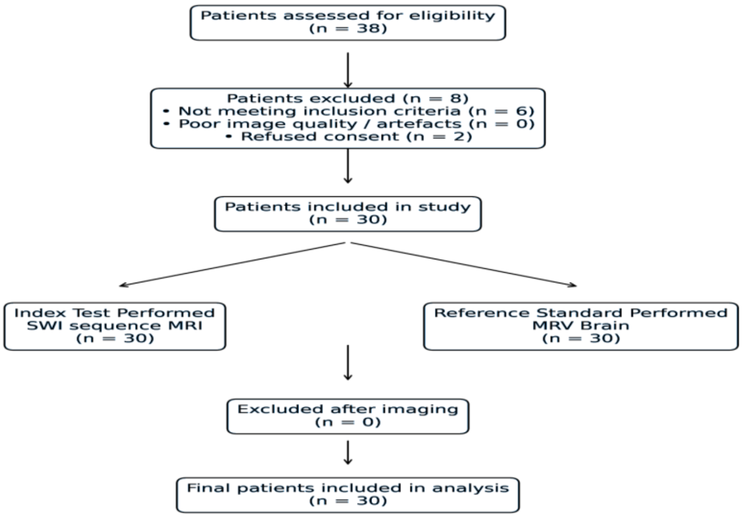
MRI protocol:

All scans are conducted on a Phillips Achieva 1.5T MRI with a four-channel head coil. No particular preparation was recommended. Only a few of patients necessitated sedation or anaesthesia assistance. All participants in the study underwent DWI, ADC, T1-weighted, T2-weighted, FLAIR and SWI imaging, in addition to 3DPC MR Venogram. Dural sinus thrombosis in axial T2-weighted image is seen as a hypointense signal in the sinus resembling a flow void, whereas the axial gradient echo image (SWI) shows blooming within the sinus. Phase contrast MR venography confirms sinus occlusion by indicating the lack of flow voids within the sinus. All MRI scans were evaluated by a single expert radiologist, with clinical correlation provided by a single neurologist. The reviewers unanimously concurred on the visibility of thrombosis across the assessed imaging sequences in conjunction with clinical suspicion. The evaluation of venous sinus thrombosis visualization was conducted according to the following criteria: Visible (1-1 high signal, 1-2 low signal), Iso signal (inadequate for diagnosis), and not visualised.

Data Collection

The study involved data collection conducted over three sessions by a senior consultant radiologist. During the initial session, observations on MRV were documented individually for each sinus and deep vein. Subsequently, additional sequences were examined for any parenchymal alterations. The findings of the SWI were documented in a distinct session. The correlation between SW1 and MRV were conducted in connection to each other and with the final diagnosis, which was determined by comprehensive imaging and clinical characteristics. Data regarding the demographic, clinical, and radiological profiles was gathered utilizing a proforma that encompassed multiple parameters, including age, sex, clinical manifestations (headache, visual disturbances, seizures, focal neurological deficits, features of elevated intracranial pressure) and MRI brain findings from diffusion-weighted imaging, T1, T2, T2 FLAIR, SWI sequences and phase contrast venography.

The collected data were input into SPSS software (version 18, SPSS Inc. IBM). Thrombus presence in each sinus or cortical vein was recorded. Cases were categorized into three groups—normal, undetermined, and thrombus-positive—based on the presence of thrombus in each sinus, utilizing MRV vs SWI sequences for comparison. The STARD 2015 graphic was utilized to illustrate the movement of participants throughout the trial.



STARD flow diagram showing patient enrolment, exclusion, and inclusion for diagnostic accuracy analysis comparing susceptibility weighted imaging (SWI) MRI with MR venography (MRV) brain.

Data analysis: Single variables were shown as percentages. P value of less than 0.05 was deemed significant. All confidence intervals (CIs) were established at 95%. The efficacy analysis of the test was determined using a 95% confidence interval for the difference in proportions.
The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of the test were computed utilizing the final disease prevalence, together with the counts of true positives, true negatives, false positives, and false negatives derived from each diagnostic assessment.
The Pearson chi-square test was computed using crosstabulation of SW1 and MRV sequences for each individual sinus. The agreement of the test was evaluated using the kappa statistic. The formula for calculating kappa is: K = PR (e), where Pr (a) represents the observed agreement among rater's and Pr (e) denotes the theoretical likelihood of chance agreement among rater's. The magnitude of the kappa coefficients is interpreted in a bar chart as follows: 0.01-0.20 mild; 0.21-0.40 fair; 0.41-0.60 moderate; 0.61-0.80 significant; 0.81-1.00 nearly perfect.

Ethics statement: All the information necessary for the conduct of the study was collected, with the approval of the Institutional Ethics Committee.

RESULTS

Total of 30 cases were included in the study who presented with headache and suspected CVT and had undergone both MRV and SWI sequences in addition to the routine MRI brain sequences.

Baseline characteristics: Out of 30 cases 21 were females and 9 were male patients. Age range of study cases were between 18 to 73 years. Mean age was 46 years. Baseline characteristics of study sample are shown in table 1. It was observed that out of 30 cases, 18(60%) cases had CVT. [Table 1]

Table 1: Baseline characteristics of the study cases

Variables	Number (%)
Total cases	30 (100%)
Males	9 (30%)
Females	21 (70%)
Headache	100 (100%)
Seizures	9 (30%)
Focal deficit	13 (43%)
Raised ICT (Intracranial tension)	4 (13.33%)
CVT (Cerebral venous thrombosis)	18 (60%)
Normal venogram	12 (40%)
Susceptible weighted images (SW1) suboptimal	1(3%)

Cortical vein thrombosis	13(43%)
Parenchymal involvement	8 (27%)

Diagnostic performance of SWI sequence of brain versus MRV brain: Out of 30 cases, clinical features combined with MRV confirmed presence of CVT in 18 cases.

MRV alone confirmed thrombus in 16 cases, normal in 13 cases and indeterminate in 1case. Sensitivity of MRV in detecting venous thrombus was 92.1%, specificity was 100%, positive predictive value was 100 %, and negative predictive value of 88.64% and diagnostic accuracy of the test is 89.45% with 95% confidence interval (CI) of 87.96% to 97.36%.

SWI detected thrombosis in 18 cases, normal in 10 cases and was inconclusive or indeterminate in 2 cases. Overall sensitivity of SW1 was 69.22%, specificity 94.33%, positive predictive value 91.65%, negative predictive value of 69.33% and diagnostic accuracy of 79.61%. 95% confidence interval was higher for specificity (64.87% to 98.81%) and positive predictive value (61.68% to 99.02% Sensitivity of SWI in comparison to MRV in case of superior sagittal sinus was 91% and specificity was 95.9%. Similarly, sensitivity of SWI in case of straight sinus was 86.9% and specificity was 97.9%.

There existed percentage of concordance and discordance between both studies. We found a higher concordance than discordance on comparing SWI from MRV for various sinuses studied (Figure 2)

COHEN KAPPA

The Cohen's kappa study reveals variable inter-modality agreement between MR venography (MRV) and susceptibility-weighted imaging (SWI) in several components of the cerebral venous system (Figure 1). Strong concordance was noted for the superior sagittal sinus ($\kappa = 0.743$) and straight sinus ($\kappa = 0.663$), signifying that both MRV and SWI yield consistent and dependable evaluations of the principal midline venous sinuses. This congruence is likely due to the considerable large calibre, central positioning, and consistent uniform flow characteristics of these sinuses, facilitating good visualization by both flow-dependent and susceptibility-based imaging modalities. Figure 3 shows the imaging appearance in a patient presenting with headache who was diagnosed with CVT

A moderate level of agreement was observed for the deep venous system ($\kappa = 0.45$). Despite SWI's intrinsic sensitivity to venous blood products and deoxygenated haemoglobin, variations in venous diameter(calibre) and partial volume effects may explain the diminished concordance relative to MRV. Nonetheless, the observed kappa value indicates that SWI continues to be a valuable adjunctive method for assessing deep cerebral veins.

The transverse sinuses exhibited moderate concordance (right $\kappa = 0.383$, left $\kappa = 0.394$). This diminished concordance may indicate prevalent anatomical asymmetry, dominance patterns, and flow-related signal attenuation on MRV, in addition to blooming and susceptibility abnormalities on SWI. These modality-dependent discrepancies underscore the constraints of depending on a singular imaging approach for evaluating the lateral venous sinuses.

Conversely, there was inadequate concordance for the sigmoid sinuses (right $\kappa = 0.121$, left $\kappa = 0.147$). Although a statistically significant association was observed in chi-square testing, the low kappa values likely indicate the acknowledged kappa paradox, where skewed prevalence and substantial marginal imbalance—such as unilateral dominance or hypoplasia of the sigmoid sinus—lead to an underestimation of actual agreement. Moreover, intricate flow dynamics and susceptibility artefacts in the sigmoid region further exacerbate inter-modality variability.

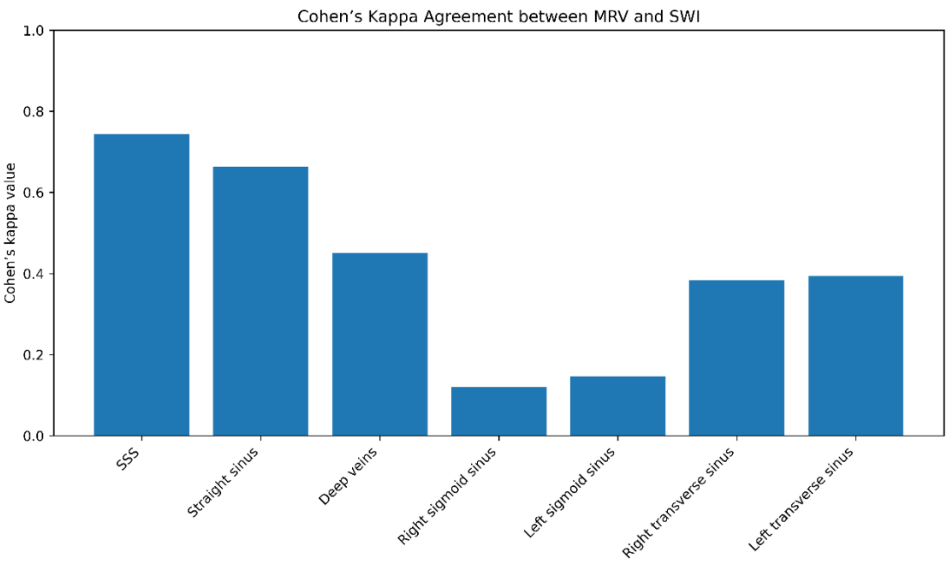


Figure 1: Measure of agreement Cohen's kappa

The Cohen's kappa bar chart illustrates that whereas MRV and SWI exhibit strong concordance for midline venous structures, the agreement diminishes steadily towards the lateral venous sinuses. These findings endorse a unified interpretation of MRV and SWI, especially for an exhaustive assessment of the cerebral venous system, and advise against excessive dependence on kappa values in isolation, without accounting for percentage agreement and anatomical variability.

Table-2: Summary of the results: agreement among MRV and SW1 MRI methods for the parameters considered. Significance calculated with the chi square score and degree of freedom

Parameters (MRV Vs SW1)	**Percentage of Agreement (concordance)**	**Chi square score**	**Degree of freedom(df)**	**P value**
SSS	89	79.37	4	<0.00001
Straight sinus	89	71.41	4	<0.00001
Deep veins	84	34.51	2	<0.00001
Right sigmoid sinus	42	18.59	4	0.001
Left sigmoid sinus	45	28.71	4	
Right transverse sinus	61	43.95	4	<0.00001
Left transverse sinus	63	49.97	4	<0.00001

Accuracy of SWI in detecting superficial cortical vein thrombosis was 97.6% (CI: 92.96% to 99.76%), with sensitivity of 100 % (CI: 90.97% to 100%), specificity of 96.7% (CI: 88.65%to 99.60%), positive predictive value of 96.44 % (CI: 83.30% to 98.70%), negative predictive value of 100%. All cases with definite thrombus on MRV turned out to be positive for CVT irrespective of SW1 features while all cases with definitely normal MRV were classified as negative for CVT irrespective of SW1 features except for 2 cases with superficial cortical thrombosis detected on SW1 sequence. Figure 4 demonstrates greater ability of SWI in picking up cortical vein thrombosis not seen well on MRV image.

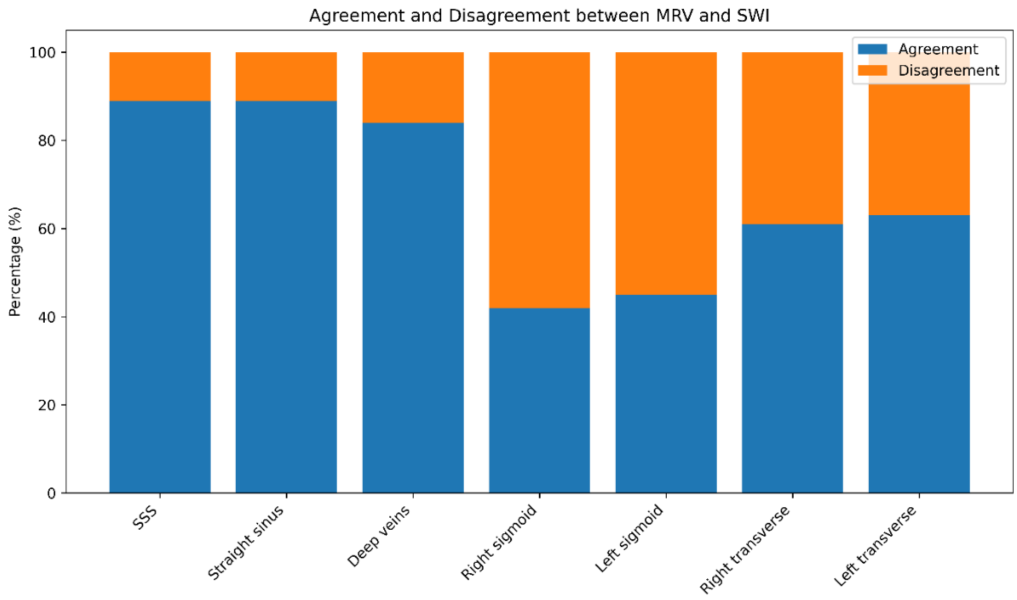


Figure 2: Percentage of agreement and disagreement in various sinuses studied using MRV and SW1 sequences

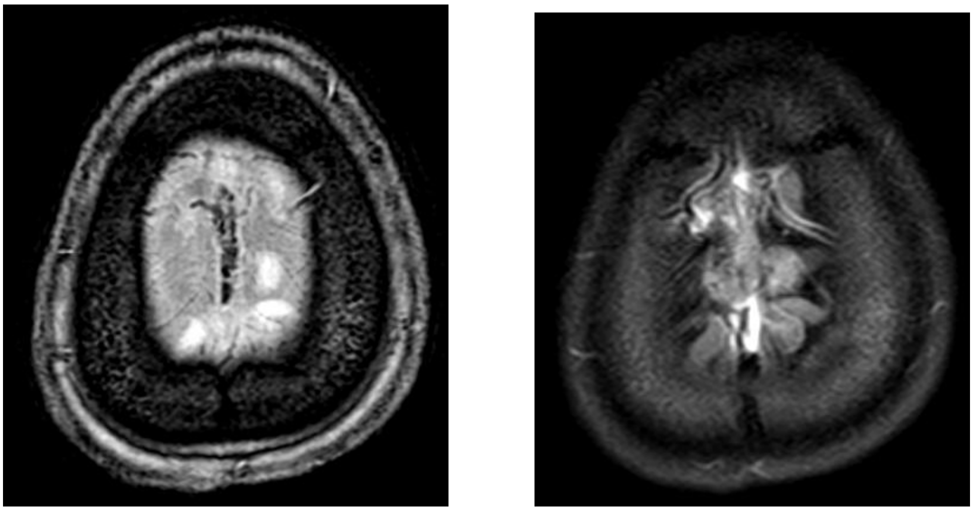


Figure 3 a) SWI image in a patient presenting with headache showing blooming in the superior sagittal sinus b) Phase Contrast MR image axial section in the same patient showing non opacification in the superior sagittal sinus confirming thrombosis

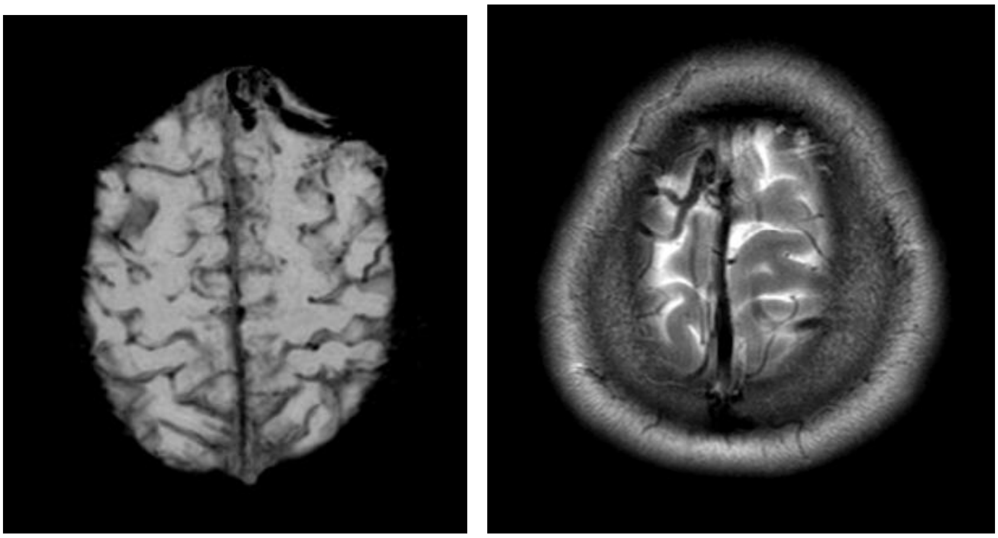


Figure 4- a) SWI image showing blooming in the anterior aspect of superior sagittal sinus and adjacent cortical vein b) Contrast MRI image showing filling defect in anterior aspect of superior sagittal sinus. Adjacent cortical vein thrombosis is better seen on the gradient images in (a)

Summary of result: Consensus between MRV and SWI. Multiple MRI techniques for the parameters were evaluated. A greater proportion of concordance is observed between MRV and SWI for the superior sagittal sinus (SSS) and straight sinus, followed by deep veins, transverse sinus, and sigmoid sinus. MRV continues to be the preferred gold standard for CVT, as evidenced by the large p-value derived from the cross-tabulation of individual sinuses, as illustrated in Table 2. SWI continues to be the superior imaging sequence for identifying superficial cortical vein thrombosis, in which MRV is suboptimal.

DISCUSSION

CVT is a disorder that generally affects young to middle-aged persons, with potentially grave consequences.(6) In India, thirty percent of stroke cases include young individuals, with cerebral venous thrombosis representing 10 to 20 percent of these instances.(7) Numerous obstacles in diagnosing cerebral venous thrombosis stem from the multitude of risk factors and variable clinical manifestations. Therefore, it is imperative to have an elevated index of suspicion for this condition to enable prompt diagnosis and intervention.

CVT represents one of the uncommon etiologies of intracerebral haemorrhage where anticoagulation therapy remains the cornerstone of treatment. As anticoagulation is generally contraindicated in most cases of intracranial haemorrhage, achieving diagnostic certainty becomes essential, thereby increasing the complexity of radiological evaluation. (8)

Magnetic resonance venography (MRV) techniques such as two-dimensional (2D) time-of-flight (TOF) and three-dimensional (3D) phase-contrast imaging are non-contrast venographic methods that demonstrate CVT by depicting absence of normal flow-related signal within the affected sinus. These techniques are particularly valuable when administration of contrast agents is contraindicated, such as in pregnancy or severe renal impairment. (9)

Headache was the most common presenting symptom in our study cohort (100%), followed by focal deficits (43%) and seizures (30%). These findings are consistent with previous reports identifying headache as the predominant clinical manifestation of cerebral venous sinus thrombosis. (10,11). Figure 3 shows the imaging appearance in a patient presenting with headache who was diagnosed with CVT.

Contrast-enhanced MRV may efficiently detect thrombosis in sinuses and small veins, as well as delineate collateral circulation and its characteristics. Conventional MRI is ineffective for detecting CVT, as it is frequently difficult to determine if the signal detected in cerebral veins indicates flow or thrombosis. MRV has limitations in its ability to visualize slowly flowing blood in small channels, including cortical veins. SW imaging leverages the phase disparity between a vessel and its adjacent parenchyma, utilizing paramagnetic deoxyhaemoglobin as an inherent contrast agent. (12,13) Thus, SW images that incorporate both phase and magnitude information improve CVT detection, which is otherwise difficult with standard MRI imaging alone.

SWI detected thrombosis in the sinuses, deep veins, and cortical veins. SWI demonstrated higher efficacy in detecting cerebral vein thrombosis compared to MRV. In cases where MRV could not identify cerebral vein thrombosis, the SW1 sequencing successfully detected it. The diagnostic precision of SWI in detecting superficial cortical vein thrombosis was 97.6%. The SWI sequence exhibited a greater proportion of indeterminate cases relative to MRV (29% compared to 5%). Therefore, MRV is the recommended diagnostic criterion for CVT. The sensitivity and specificity of SW1 in diagnosing superior sagittal and straight sinus thrombosis were analogous to those of MRV. Consequently, conventional MRI with SW1 would aid in verifying CVT in most instances based on clinical history. (14)

This may help reduce the expenses related to diagnosing CVT when MRV is not feasible due to financial constraints. Secondly, MRV contrast is labor-intensive and presents a danger of contrast exposure. The study is constrained by a limited sample size. The research focused on picture analysis and its relationship with clinical data. The merit of our work is in its position as the first inquiry to compare the diagnostic accuracy of SWI brain imaging with MRV in cases of CVT from Asia. Secondly, we sought to evaluate the diagnostic efficacy of both sequences by including normal patients without CVT in addition to those with CVT. SWI is the definitive imaging sequence for detecting isolated superficial cortical vein thrombosis.

CONCLUSION

Our research concluded that MRV continues to be the gold standard for diagnosing CVT. A degree of consensus exists between MRV and SW1 sequences.

Both sequences (MRV and SW1 sequence) exhibit significant concordance in cases of superior sagittal sinus thrombosis and straight sinus thrombosis. SWI is the benchmark for diagnosing isolated superficial cortical vein thrombosis. Conventional MRI with SWI would assist in confirming CVT in most instances when MRV is impractical. Nonetheless, extensive randomized trials will be necessary to validate its effectiveness as a diagnostic tool.

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