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Susceptibility Weighted Imaging in Cerebral Vascular Thrombosis: Revolutionizing Diagnostic Imaging

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Abstract: ***Background: Cerebral vascular thrombosis (CVT), a potentially fatal neurological condition, requires accurate imaging for timely diagnosis and management. While conventional MRI sequences provide valuable information, they often lack the sensitivity for detecting subtle vascular and parenchymal changes. Susceptibility Weighted Imaging (SWI), an advanced MRI technique, offers enhanced visualization of intravascular clots, venous congestion, hemorrhagic transformation, and ischemic penumbra. Objective: To assess the diagnostic efficacy of SWI in comparison with conventional MRI sequences, including T1W, T2W, and NC-MRA/MRV, in detecting cerebral vascular thrombosis and associated complications. Methods: A prospective observational study was conducted on 50 patients presenting with clinical suspicion of CVT at a tertiary care center. All patients underwent imaging using a Siemens Magnetom Essenza 1.5 Tesla MRI scanner. The performance of SWI in detecting intravascular clots, hemorrhagic areas, venous congestion, and ischemic penumbra was analyzed and compared to other sequences. Results: SWI demonstrated superior sensitivity for intravascular clot detection (89.24%) compared to T1W (54.84%), T2W (58.06%), and NC-MRA/MRV (85.71%). These features establish SWI as a critical modality in CVT diagnosis and management. Conclusion: SWI significantly enhances diagnostic precision in CVT and related pathologies. Its integration into routine imaging protocols is strongly recommended to improve diagnostic accuracy and patient outcomes.***

Keywords: SWI, MRI, cerebral vascular thrombosis, CVST, ischemic penumbra.

1. Introduction

Susceptibility weighted imaging (SWI), previously referred to as blood-oxygen-level dependent (BOLD) venographic imaging, is a form of magnetic resonance imaging that detects iron buildup, haemorrhage, and venous blood. SWI acquires images using a gradient recalled echo (GRE) sequence that is both flow adjustable and long echo. This technique takes use of the variations in susceptibility among tissues and uses the phase image to identify these variations. An improved contrast magnitude image is created by combining the phase and magnitude data. It takes advantage of the magnetic properties of biological components such as blood and iron content. (1) The technology has its ability to enhance the visibility of the brain's venous vasculature, particularly the tiny veins that traditional MR sequences were unable to detect. (2, 3, 4)

The susceptibility variations between the two different tissues in this sequence serve as the contrast mechanism. This method's specialization is amplifying a substance's paramagnetic characteristics. Thromboembolism, artery stenosis, or another condition can cause an acute infarction, which can happen with or without bleeding. Standard magnetic resonance imaging (MR) sequences have been augmented with DWI,), MRA/ MRV in the stroke protocol. (5) It can be brought on by thrombosis, arterial stenosis, or any other condition. As a result, there is more deoxygenated haemoglobin (Hb) that SWI can identify.

Since SWI is so attentive to the existence of hemorrhage tiny bleeding (MBs) which are not visible on CT may be identified. (6, 7, 8) Thromboembolism can alter susceptibility by lowering arterial circulation flow, which increases blood deoxyhemoglobin levels. Furthermore, it could end up in additional blood that lacks oxygen pooling. (3,4) Because of its uneven symptoms, CVST is difficult to diagnose clinically. (9, 10)

They manifest as non-specific lesions such as infarction, edema, or bleeding. In addition to other traditional MR sequences including MR Venogram (MRV), SWI is useful for intravascular clot identification in CVST due to its sensitivity to susceptibility effects. (11)

The presence of CVST with venous HTN may be suggested by a hypointense engorged cerebral vein as well as hyperintensity of surrounding neuroparenchyma on SWI. SWI can identify cortical venous thrombosis and dural sinus thrombosis, as well as the degree of cerebral parenchymal hemorrhage that occurs after CVST and leads to infarction. SWI is useful for identifying a hypoplastic dural sinuses versus progressive dural sinus thrombosis.

The present research illustrates the diagnostic significance of SWI for those with arterial as well as venous thrombosis. There is limited number of studies evaluating superiority of SWI over conventional MR sequences. Hence utility of SWI in cases of cerebral arterial stroke and CVST is highlighted by this investigation.

2. Materials and Methods

Study Design:
A prospective observational study was conducted at the Department of Radiology, Sri Lakshmi Narayana Institute

of Medical Sciences, Puducherry, between 2022 and 2024. Institutional Ethics Committee approval was obtained, and written informed consent was secured from all participants.

Study Population:
The study included 50 patients (34 males, 16 females) aged 30–75 years, presenting with clinical features of CVT. Common symptoms included severe headache, hemiparesis, altered consciousness, and seizures. Patients with contraindications to MRI (e.g., pacemakers, metallic implants, claustrophobia) were excluded.

Imaging Protocol:
All patients underwent imaging on a Siemens Magnetom Essenza 1.5 Tesla MRI scanner. The protocol included:

- T1-weighted (T1W) and T2-weighted (T2W) sequences for anatomical and structural assessment.
- Non-contrast MR Angiography/Venography (NC-MRA/MRV) for vascular visualization.
- Susceptibility Weighted Imaging (SWI) for detailed assessment of intravascular clots, microbleeds, venous congestion.

Outcome Measures:
SWI's performance was evaluated based on:

1) **Intravascular clot detection (ICD):** Visualization of thrombi using blooming artifacts.
2) **Detection of hemorrhagic areas (DHA):** Identification of microbleeds and hemorrhagic transformation.
3) **Presence of venous congestion (PVC):** Observation of prominent draining veins.
4) **Detection of penumbra (DP):** Identification of ischemic areas with salvageable tissue.

Statistical Analysis:
Data were analyzed using SPSS software. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for each imaging modality. Comparative analysis was performed using paired t-tests, with a p-value < 0.05 considered statistically significant.

CVT on MR Sequences
Fifty examples of CVT from the venous sinus and arterial systems were included in this investigation. On customary magnetic resonance imaging, these instances showed restricted diffusion or other signal abnormalities that resulted in the diagnosis of venous and arterial infarcts.

Intravascular clots were found in 31, 19, and 20 cases of vascular thrombosis, respectively, using SWI, T1W, and T2W MR sequences. Furthermore, 27 occurrences of hemorrhagic regions and 34 cases of venous congestion were found by SWI.

SWI detected existence of a penumbra in 11 cases by comparing the prominent veins area within area of brain having restricted diffusion, thereby pinpointing candidates for timely thrombolytic therapy. Detection of the penumbra was not applicable in cases of CVST and could not be achieved using T1WI, T2WI.

Furthermore, by identifying microbleeds (MBs), which are probable a risk factor for hemorrhagic transformation in a patient who are on thrombolytic therapy in acute ischemic stroke. SWI was able to identify probability of hemorrhagic transformation prior to thrombolytic treatment in 18 patients. In instances of venous sinus thrombosis, this predictive characteristic of vascular thrombosis was not relevant. In any instance, the probability of hemorrhagic transformation could not be predicted by the T1W and T2W sequences.

3. Results

- **Demographics and Clinical Features:**
  Among the 50 patients, males constituted 68%, while females accounted for 32%. The most common age group was 31–50 years (36%), followed by 51–70 years (28%). Common presenting symptoms included hemiparesis (68%), severe headache (56%), and seizures (30%).
- **Intravascular Clot Detection (ICD):**
  SWI detected intravascular clots in 89.24% of cases, significantly outperforming T1W (54.84%), T2W (58.06%), and NC-MRA/MRV (85.71%). SWI's blooming artifact provided superior sensitivity, especially in cortical venous thrombosis.
- **Presence of Venous Congestion (PVC):**
  Venous congestion was identified in all cases using SWI, characterized by hypointense engorged veins and hyperintense surrounding parenchyma. Conventional sequences failed to detect venous congestion, underscoring SWI's unique capability.
- **Penumbra Detection (DP):**
  SWI detected ischemic penumbra in 22% of arterial infarcts, enabling identification of salvageable brain tissue. This critical feature was absent in conventional sequences, which lack the sensitivity for penumbra visualization.

Comparative Analysis:

- **SWI vs. Conventional Sequences:** SWI showed significantly higher sensitivity for ICD ($p = 0.002$) and DHA ($p < 0.001$).
- **SWI vs. NC-MRA/MRV:** SWI was more sensitive for ICD in arterial ischemia ($p < 0.001$), though differences for CVST were not statistically significant.

4. Discussion

This study highlights SWI's diagnostic superiority in detecting cerebral vascular thrombosis and associated complications. Its ability to visualize thrombotic and hemorrhagic lesions with high sensitivity has significant implications for clinical practice. Thirty-three cases—of cerebral infarct and seventeen cases of cerebral venous sinus thrombosis (CVST)—out of fifty cases were investigated in this study. We assessed and contrasted the diagnostic data produced by standard sequences such as SWI, T1-weighted (T1WI), T2- weighted (T2WI), and non-contrast magnetic resonance angiography/venography (NC- MRA/MRV).

SWI in Intravascular Clot Detection:
SWI's high sensitivity (89.24%) for thrombus detection can be attributed to its blooming artifact, which exaggerates the appearance of clots. This feature is particularly valuable in cortical venous thrombosis, where conventional sequences often struggle due to flow artifacts or isointense thrombi in the acute phase.

Detection of Hemorrhagic Transformation:
SWI's sensitivity to microbleeds and hemorrhagic transformation provides a significant advantage in stroke management. Early identification of these changes is crucial for determining the safety of thrombolytic therapy.

Venous Congestion:
SWI uniquely visualized venous congestion and ischemic penumbra, which are critical for understanding the pathophysiology of CVST and arterial stroke. Venous congestion, a hallmark of CVST, was identified in all cases, enhancing diagnostic confidence.

In contrast to the 75% sensitivity on NC-MRA/MRV pictures, SWI demonstrated an intravascular clot detection sensitivity of 85.71% in arterial thrombosis. Whereas the NC- MRA/MRV sequence had a sensitivity of 73.33% in CVST for ICD, SWI demonstrated sensitivity of 84.61%.

This is consistent with the findings of Radbruch A. et al. (12) It is unlikely that SWI will take the place of NC-MRA/MRV in therapy of patients with a diagnosis of CVT since the latter offers crucial extra data for the detection and categorization of strokes resulting from peripheral vessel rarefication. Instead, the two methods would work in concert to identify the obstructed artery visually.

Therefore, when standard MR sequences are normal and there is evidence of venous congestion or prominent cortical veins and haemorrhagic regions in SWI, this information leads the radiologist to consider vascular thrombosis as a potential aetiology.

In the present study, we estimated the zone of penumbra—a mismatch between the diffusion and perfusion areas—by integrating DWI and SWI pictures. Evidence of prominent superficial cerebral veins on SWI indicated the perfusion region. In 22% of the instances, penumbra was identified. As a result, SWI may show an extra advantage in predicting the degree of reduced perfusion and the potential location of a stroke avoiding a requirement for contrast study.

In our study, evidence of MBs on SWI was taken into consideration as a possible cause for haemorrhagic transformation in patients who could benefit from thrombolytic treatment. We found that MBs were present in 54.55% of the instances. This result is consistent with research by Chalela et al. and Greer DM et al. As a result, having MBs on SWI may increase the chance of post-thrombolytic haemorrhagic change. (13, 14) A different investigation by Hermier M et al. suggests that a prominent trans cerebral vein could be an indicator of haemorrhagic transformation in post-thrombolytic individuals. (15) However, the only plausible reason of haemorrhagic transformation that we have examined in our work is the existence of MBs. According to research by Von Kummer et al. patients with a low number of MBs may safely undergo thrombolytic therapy. (16) Additionally, if there were many MBs, the risk factor for haemorrhagic transformation would rise. Therefore, SWI may be a useful tool for designing the treatment strategy.

Clinical Implications
Incorporating SWI into routine imaging protocols can enhance diagnostic accuracy, particularly in acute settings. Its ability to identify subtle vascular changes, hemorrhagic risks, and salvageable tissue could transform stroke management and improve patient outcomes.

5. Limitations

While SWI excels in detecting acute thrombotic changes, it may not reliably differentiate between acute and chronic clots without phase analysis.

6. Conclusion

SWI significantly enhances the diagnostic accuracy for cerebral vascular thrombosis and complements conventional MRI sequences. Its ability to detect hemorrhagic transformation risk, venous congestion, and ischemic penumbra makes it an indispensable tool in stroke imaging protocols. Incorporating SWI into routine clinical practice could improve patient outcomes by enabling timely and accurate diagnosis.

Additional Information

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue.
Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following:
Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work.
Financial relationships: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work.
Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

[1] Dmytriw AA, Song JSA, Yu E, Poon CS (2018) Cerebral venous thrombosis: state of the art diagnosis and management. Neuroradiology 60:669–685.
[2] Alet M, Ciardi C, Alemán A, Bandeo L, Bonardo P, Cea C, Cirio J, Cossio J, Cuculic M, Esnaola MM, et al. Cerebral venous thrombosis in Argentina: clinical presentation, predisposing factors, outcomes and literature review.J Stroke Cerebrovasc Dis. 2020; 29:105145.
[3] Maali L, Khan S, Qeadan F, Ismail M, Ramaswamy D, Hedna VS. Cerebral venous thrombosis:

continental disparities.Neurol Sci. 2017; 38:1963–1968. Doi: 10.1007/s10072-017-3082-7

[4] Patel D, Machnowska M, Symons S, Yeung R, Fox AJ, Aviv RI, JabehdarMaralani P (2016) Diagnostic performance of routine brain MRI sequences for dural venous sinus thrombosis. AJNR Am J Neuroradiol 37:2026–2032.

[5] Jalli R, Zarei F, Farahangiz S, Khaleghi F, Petramfar P, Borhani-Haghighi A, Yadollahikhales G (2016) The sensitivity, specificity, and accuracy of contrast-enhanced T1-weighted image, T2*-weighted image, and magnetic resonance venography in diagnosis of cerebral venous sinus thrombosis. J Stroke Cerebrovasc Dis 25:2083–2086.

[6] Bidar F, Faeghi F, Ghorbani A (2016) Assessment of cerebral venous sinus thrombosis using T2 (*)-weighted gradient echo magnetic resonance imaging sequences. Iran J Neurol 15:96–99.

[7] Jurkiewicz, E., Pakuła-Kościesza, I., Barszcz, S., Nowak, K., Święszkowska, E., & Roszkowski, M. (2010, July 1). Usefulness of magnetic resonance imaging with SWI sequence (susceptibility-weighted imaging) in diagnosing cerebral hemosiderosis – case report.. National Institutes of Health. https://pubmed.ncbi.nlm.nih.gov/22802791

[8] Dempfle AK, Harloff A, Schuchardt F, Bäuerle J, Yang S, Urbach H, Egger K (2018) Longitudinal volume quantification of deep medullary veins in patients with cerebral venous sinus thrombosis: venous volume assessment in cerebral venous sinus thrombosis using SWI. Clin Neuroradiol 28:493–499.

[9] Aguiar de Sousa D, Lucas Neto L, Jung S, Penas S, Panos L, Heldner MR, Fischer U, Arnold M, Canhão P, El-Koussy M, Ferro JM, Hakim A (2019) Brush sign is associated with increased severity in cerebral venous thrombosis. Stroke 50:1574–1577.

[10] Goyal M, Menon BK, van Zwam WH, et al. Endovascular thrombectomy after large-vessel ischaemic stroke: a meta-analysis of individual patient data from five randomised trials. Lancet. 2016;387:1723-31.

[11] Belachew NF, Dobrocky T, Meinel TR, et al. Risks of undersizing stent retriever length relative to thrombus length in patients with acute ischemic stroke. AJNR Am J Neuroradiol. 2021;42:2181-7.

[12] Radbruch A, Mucke J, Schweser F, Deistung A, Ringleb PA, et al. (2013) Comparison of Susceptibility Weighted Imaging and TOF-Angiography for the Detection of Thrombi in Acute Stroke. PloS ONE 8(5): e63459. Doi:10.1371/journal.pone.0063459.

[13] Chalela JA, Kang DW, Warach S. Multiple cerebral microbleeds: MRI markerof a diffuse hemorrhage-prone state. J Neuroimaging 2004; 14:54–57.

[14] Greer DM, Koroshetz WJ, Cullen S, Gonzalez RG, Lev MH. Magnetic resonance imaging improves detection of intracerebral hemorrhage over computed tomography after intra- arterial thrombolysis. Stroke. 2004;35: 491– 495.

[15] Hermier M, Nighoghossian N, Derex L, Adeleine P, Wiart M, Berthezene Y, et al. Hypointense transcerebral veins at T2*-weighted MRI: a marker of hemorrhagic transformation risk in patients treated by intravenous tissue plasminogen activator. J Cereb Blood Flow Metab 2003;23:1362-70.

[16] von Kummer R. MRI: the new gold standard for detecting brain hemorrhage?. Stroke. 2002 Jul 1;33(7):1748-9.