ORIGINAL RESEARCH

Role of Susceptibility-Weighted Imaging Inevaluation of Acute Ischemic Stroke

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ABSTRACT

Background:Stroke causes mortality and disability. Thrombolytic therapy is standard for ischemic strokes up to 4.5 h after symptoms. Although artery occlusion can be diagnosed by DSA, MRA, and CTA, thrombus composition and development timeframes may not be known. SWI is used to detect thrombus in acute ischemic stroke. SWI can indicate a thrombus as a hypointense SVS.Wecompared the detection of hemorrhage by using susceptibility weighted imaging (SWI) with T1, T2 and Fluid attenuation inversion recovery (FLAIR) sequences in acute stroke.

Materials and Methods: From October 2020 to October 2021, 150 patients with suspected acute stroke were examined prospectively at Kakatiya Medical College/MGM Hospital Warangal using the above sequences. Acute infract haemorrhage detection was evaluated and compared.

Results: In 58 individuals, 48 had arterial infarcts and 10 had venous infarcts. Hemorrhage affected 38 (25.33%) of 94 male patients and 18 (12%) of 56 female patients.When compared to T1, T2, and FLAIR, SWI was significantly more sensitive and specific (p value 0.0031) for detecting haemorrhage in acute infract. There were 26 (17.33%) cases of Susceptibility sign, which indicates an intravascular thrombus.

Conclusion: SWI is the most effective sequence for detecting haemorrhage in acute infracts. It can also determine the source of an infraction by detecting the susceptibility sign. The SWI sequence must be included in the protocol for evaluating patients with acute stroke.

Keywords: stroke; Magnetic Resonance Imaging, MRI, susceptibility weighted imaging (SWI), (PWI), DW.

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INTRODUCTION

A stroke occurs when the blood supply to the brain is cut off, usually due to a blood vessel burst or being blocked by a clot. This reduces the supply of oxygen and nutrients, causing brain tissue damage.[1] The consequences of a stroke are determined by which part of the brain is injured and how severely it is damaged. Because a very severe stroke can result in death, predicting the risk of further infarct growth in stroke patients is critical for therapeutic decision making.[2] The concept of penumbra, which is an area with reduced blood flow but not to the point of irreversible cell membrane failure, underpins modern therapy for acute ischemic stroke. Despite several limitations, mismatch between larger abnormal areas on MR perfusion-weighted imaging (PWI) and smaller restricted areas on diffusion-weighted imaging (DWI) is a widely accepted approach to detecting penumbra, predicting stroke evolution, and identifying patients with the greatest potential to benefit from thrombolytic therapy. PWI, on the other hand, necessitates the use of a contrast agent, which is contraindicated in a number of clinical situations, including renal insufficiency and previous reactions to contrast agents.[3]

In the setting of an acute stroke, MRI provides critical information that can be used to confirm a diagnosis and guide both acute therapeutic interventions and long-term treatment decisions. Active ischemia, haemorrhage, and vessel occlusion can all be detected using MRI. MRI has the potential to identify regions of core infarct (ischemic core) and salvageable tissue with appropriate processing (penumbra). However, in order to be the only imaging study used before thrombolysis, MRI must reliably detect acute haemorrhage. Microbleeds and petechial haemorrhages in ischemic infarction are insensitive to conventional MRI. Using susceptibility weighted imaging, MRI can detect hyperacute haemorrhage (SWI). SWI is a T2-weighted gradient echo post-processing reconstruction technique that emphasises the paramagnetic properties of blood products and is very sensitive for detecting intravascular venous deoxygenated blood as well as extravascular blood products.[4]

SWI is a powerful technique in the evaluation of stroke patients due to its ability to detect early blood products in patients with acute stroke. SWI can also help to identify the affected vascular territory. The Susceptibility sign, which appears as hypointense blooming in the vessel on the SWI sequence, indicates thrombus in the vessels.

Objectives of study;

1. To identify hemorrhagic foci in patients with acute ischaemic stroke by SWI
2. To compare the detection of hemorrhagic foci in patients with acute ischaemic stroke by SWI versus conventional MR imaging.

To identify the intra-arterial clot as depicted by the Susceptibility sign

MATERIALS & METHODS

Study design: Cross - sectional study.

Study area: The present study was conducted in the department of radiology, Kakatiya Medical College during the period of October 2020 to October 2021.

Selection Criteria

Inclusion Criteria

- All ages and sexes.
- Patients with acute symptoms of stroke in whom MR imaging is done within 7 days showing restriction on Diffusion weighted imaging (DWI).

Exclusion criteria

- Causes of hemorrhage other than acute ischemic stroke like cerebral amyloid angiopathy.
- Follow up MR imaging of asymptomatic known cases of patients with stroke or chronic stroke patients.
- Patients in whom MR imaging is clinically indicated, but cannot be performed due to conditions like cardiac pacemaker, cochlear implants, and other routine contraindications for MRI.

Source of data

All clinically suspected patients with neurological deficit (signs and symptoms like dysphasia/ aphasia, hemiparalysis / hemiparesis, ataxia, convulsions) referred by neurologist, physicians for MRI of brain f Kakatiya Medical College during the period from October 2020 to October 2021.

Sample Size: 150 patients.

Sample size calculation
Sample size was estimated by using N – master software, from the cited literature (67) assuming the proportion of stroke detected by SWI as 66.67% with relative precision of 15% and desired confidence interval of 95%, the minimal sample size required is estimated to be 88 cases for satisfactory statistical analysis.
Study period: October 2020 to October 2021.

Methodology:
Data collection
All clinically suspected patients with neurological deficit referred by neurologists, physicians for MRI of brain in Kakatiya Medical college, Warangal.

Equipments
The machine used in this study was 1.5 Tesla MRI scanner (Magnetom Avanto; Siemens Erlangen, Germany).

MRI protocol
The following sequences were performed, sagittal T1 weighted images, axial T2weighted images, Fluid attenuated inversion recovery (FLAIR), Diffusion weighted imaging (DWI) including Apparent diffusion coefficient (ADC) and Susceptibility weighted images(SWI). The parameters were as follows:
(1) T1 Weighted Imaging: Time to Repeat (TR):480 ms, Time to echo (TE): 8.7 ms; slice thickness: 5 mm; matrix size: 320 x 80; FOV: 230 mm, (2) T2 Weighted Imaging: Time to Repeat (TR): 5000 ms, Time to echo (TE): 92 ms; slice thickness: 5 mm; matrix size: 448 x70 ; FOV: 230 mm, (3) FLAIR: TR: 9000 ms; TE: 92 ms; slice thickness: 5 mm; matrix size: 256 x 85; FOV: 230 mm; Inversion time (TI): 2,500 ms; flip angle: 150° (4) Diffusion-weighted image (DWI): Echo planar imaging (EPI) spin echo; Time to Repeat (TR): 3600 ms; Time to echo (TE): 102 ms; slice thickness: 5 mm; matrix size: 192 x 100 ; FOV: 230 mm; b values 0 and 1000 s/mm 2 (3) SWI: TR: 49 ms; TE: 40 ms; slice thickness: 2.1 mm; matrix size: 512×256; FOV: 220 mm; flip angle: 20°; bandwidth, 80 kHz, acquisition time: 2.58 min (4) Magnetic resonance angiography (MRA): TR: 3.5 ms; TE: 1.1 min; slice thickness:
1.0 mm; matrix size: 192×256; FOV: 270 mm; flip angle: 30°. (5) Time-of-flight angiography (TOF MRA): TR: 36 ms; TE: 6.9 min; slice thickness: 1.4 mm; matrix size: 224×256; FOV:18 cm; flip angle: 25°.
Imaging protocol for SWI was TR – 48 ms, TE - 40ms, flip angle (FA) – 15 degrees, slice thickness –
2.5 mm, inter slice gap 0.5 mm, bandwidth - 80 kHz and field of view (FOV) – 230 x 200 mm, matrix 256 x 192 mm, acquisition time 3 minutes 29 seconds. Four sets of images were generated including phase, magnitude, SWI and minimum intensity projections and were analyzed.
Hyper intense areas on T1 weighted sequence, heterogeneous increased signalintensity in the infract area on T2 and FLAIR was considered as hemorrhage. 'Susceptibility sign' is said to be positive when the diameter of a hypointense vesselexceeds the diameter of the contralateral artery on susceptibility-weighted imaging(SWI) images. (68)
The following data was recorded – patient’s age, sex, clinical history, territory and type of infarct, extent of infarct, presence or absence of hemorrhage in SWI along with extent of hemorrhage, presence or absence of Susceptibility sign, presence of prominent cortical and/or intramedullary veins in the vicinity of infarct and presence or absence of micro bleeds.

Statistical methods
Data was entered in Microsoft excel and was analysed using SPSS version 17. All quantitative variables in the study were expressed in terms of descriptive statistics such as mean and standard deviation. All qualitative variables such as presence of hypertension, diabetes mellitus, gender etc were expressed in terms of proportion. Hemorrhagic foci in patients with acute ischaemic stroke by SWI versus conventional MR imaging was compared. P<0.05 was considered as statistically significant.

RESULTS

Table 1: Categorization of patients based on their gender.

Gender	Number (n)	Percentage (%)
Female	56	37.33
Male	94	62.67
Total	150	100.0

In this study which includes 150 patients, 94 patients were male (62.67%) and 56 (37.33%) were females.

Table 2: Distribution of age and sex of the patients.

Age in years	Gender		Total
	Female n (%)	Male n (%)	
<20	3 (2.0)	0(.0)	3(2.0)
20-29	2(1.33)	8(5.33)	10 (6.67)
30-39	5(3.33)	9(6.0)	14 (9.33)
40-49	4(2.67)	14(9.33)	16 (10.66)
50-59	6(4.0)	13(8.66)	19 (12.66)
60-69	18(12.0)	23(15.33)	41 (27.33)
70-79	17(11.33)	18(12.0)	35(23.33)
>80	3(2.0)	7(4.67)	10(6.66)
Total	58	92	150
	38.67%	61.33%	100.0%

In this study the peak incidence of neurological deficits in males occurred in the age group between 60– 69 years that is 18 patients (12 %). In females the peakincidence occurred in the age group between 70 – 79 years that is 17 patients (11.33%).

Table 3: Number of hypertensive patients in the study subjects.

Hypertension	Number (n)	Percentage (%)
Absent	91	60.66
Present	59	39.34
Total	150	100.0

In this study out of the 150 patients, 59 (39.34 %) patients had only hypertension and 91 (60.66%) patients had no history of hypertension only.

Table 4: Number of patients with both hypertension and diabetes mellitus in the study subjects.

Both Hypertension and Diabetes Mellitus	Number (n)	Percentage (%)
Absent	103	68.66

Present	47	31.34
Total	150	100.0

In this study out of the 150 patients, 47 (31.34 %) patients had both hypertension and diabetes mellitus. 103 (68.66 %) patients had no history of both hypertension and diabetes mellitus. Out of the 58 patients with hemorrhagic infarcts 20 (46.5 %) patients had hypertension and 47 (31.34 %) patients had diabetes mellitus.

Table 5: Number of patients with hemorrhage in the study.

Hemorrhage	Number (n)	Percentage (%)
Absent	92	61.33
Present	58	38.67
Total	150	100.0

Hemorrhage was detected in 58 patients, of which 48 cases were arterial infarcts and 10 were venous infarcts. Hemorrhage was seen in 38 (25.33 %) out of 94 male patients and 18 (12.0 %) out of 56 female patients.

Table 6: Number of arterial infracts in the study.

Arterial Infracts	Number (n)	Percentage (%)
Present	133	88.66
Absent	17	11.34
Total	150	100.0

In this study out of the 150 patients, 133 (88.67 %) patients had infarcts in the arterialterritory and 17 (11.34 %) patients had venous infracts.

Table 7: Number of Susceptibility sign seen in this study.

Susceptibility Sign	Number (n)	Percentage (%)
Absent	124	82.66
Present	26	17.33
Total	150	100.0

The susceptibility sign which is suggestive of acute thrombus was seen in 26 (17.33 %)patients in this study.

Table 8: Characterization of the infarct on T1 weighted imaging.

T1 weighted imaging	Number (n)	Percentage (%)
Hypointense	141	94.0
Hyper intense	9	6.0
Total	150	100.0

In this study 9 (6.0%) patients had hyperintensites in the areas of infract, which wassuggestive of hemorrhage.

Table 9: Characterization of the infarct on T2 and FLAIR sequences

T2 and FLAIR sequences	Number (n)	Percentage (%)
Hyper intense	127	84.66
Heterogeneous	23	15.34
Total	150	100.0

In this study 23 (15.34%) patients had heterogeneous signal intensities in the areas ofinfract, which was suggestive of hemorrhage.

Table 10: Detection of hemorrhage by SWI

SWI	Number (n)	Percentage (%)
No Hemorrhage	82	65.6
Hemorrhage	54	34.4
Total	150	100.0

Susceptibility weighted imaging detected hypointense blooming in the areas of infractin 54 (34.4 %) out of 150 patients. No hypointense blooming was seen in 82 (65.6 %) patients in this study.

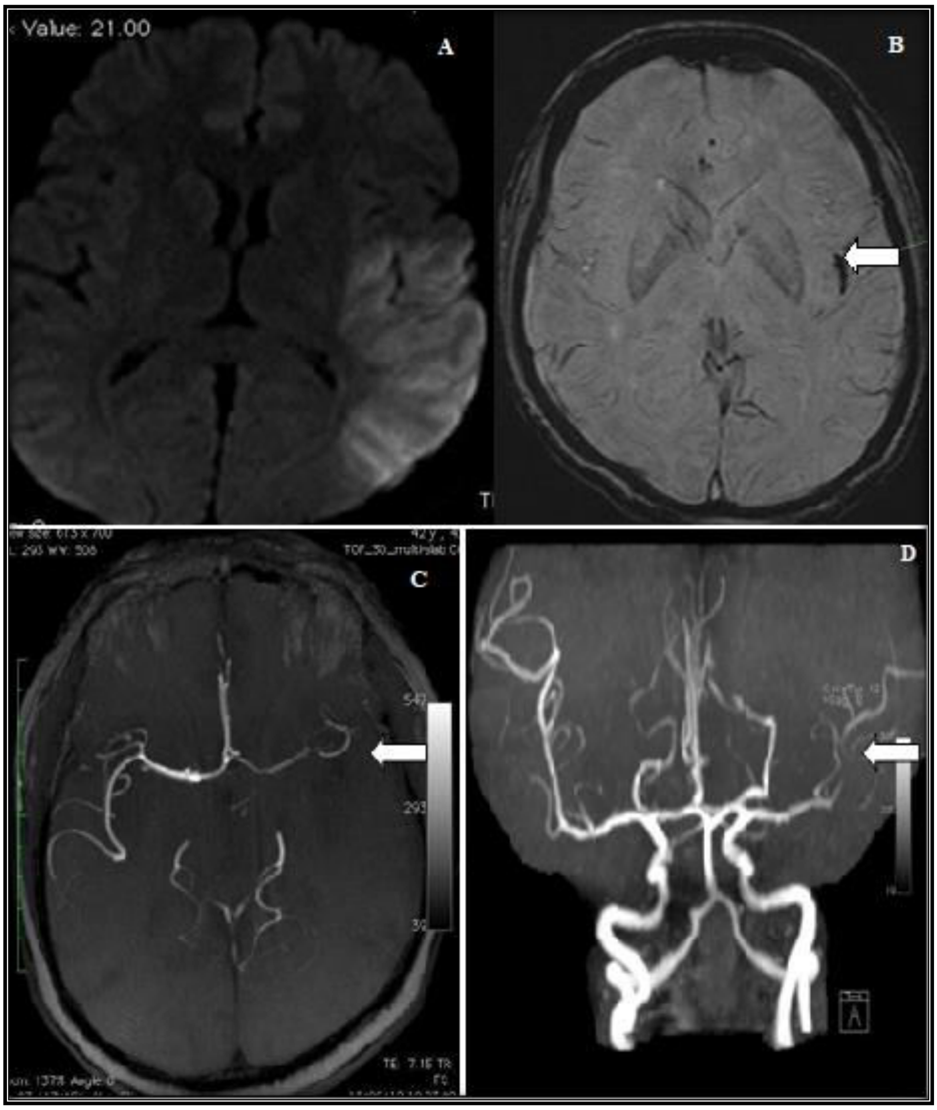

Figure 1: A. Axial Diffusion Weighted Image (DWI), B. SWI showing Susceptibility sign (arrow), C & D. Time of Flight (TOF) axial and coronal MIP image thrombosis ofthe Sylvain branches of left MCA (Arrows).

MR images of 46-year male with acute neurological deficit, showing area of diffusion restriction in the left temporo- parietal lobe suggestive of infarct. Figure B. SWI showing the suscepitiblty sign in the Sylvian branch of left MCA which was correlated with TOF angiography image showing non vasculization of the Sylvian branches of left MCA suggestive of thrombosis.

MR images of 25-year female with severe headache since 2 days. Figure a & b axial SWI showing area of hypointense blooming in the right frontal lobe suggestive of hemorrhage (blue arrow) withsuscepitiblty sign in the anterior cortical branches and anterior part of superior sagital sinus which was correlated with TOF venography image showing non vasculization of the anterior part of superior sagital sinus (white arrows) and the anterior cortical veins suggestive of thrombosis.

DISCUSSION

Susceptibility-weighted imaging (SWI) is a new technique that exploits susceptibility differences in different tissues, to provide a different type of tissue contrast. It is exquisitely sensitive to blood products, even more than the gradient-echo (GRE)technique, partly because of its inherent sensitivity, increased spatial resolution andthe thinner slices acquired.6According to the findings of this research, the highest incidence of neurological abnormalities in males was observed in the age group that ranged from 60 to 69 years old, which included 21 patients (16.8 percent). The age range of 70 to 79 years old had the highest number of cases among females, with 15 people affected by the disease at that time (12 percent).In this particular research, there were a total of 125 individuals, 45 of them had only hypertension (representing 36 percent), and 80 of these patients had no history of hypertension exclusively. [Table 4] of this studies revealed that out of 125 patients, 29.6 percent, or 37, had hypertension and diabetes mellitus together. The results showed that 88 (70.4%) of the patients did not have a previous history of either hypertension or diabetes mellitus. Twenty of the 43 patients with hemorrhagic infarcts had hypertension, which accounts for 46.5 percent of the total, and eleven of the 43 patients with hemorrhagic infarcts had diabetes mellitus, that accounts for 25.5% of the total. [Table 5] demonstrates that haemorrhage was discovered in 43 individuals, with 34 cases being arterial infarcts and 9 being venous infarcts. Hemorrhage was observed in 28 (35.8 percent) out of 78 male patients, and in 15 (31.9 percent) out of 47 female patients.In this study, [Table 6] reveals that out of 125 patients, 116 (92.8%) had infarcts in the arterial area and 9 (7.2%) had venous infarcts. [Table7] confirim In this study, the susceptibility sign, which is suggestive of acute thrombus, was observed in 17 patients, which is 13.6 percent of the total. [Table 9] reveals the following: In this particular study, there were six individuals, which is 4.8 percent, who had hyperintensites in the areas of infract, which was indicative of bleeding. [Table 10] In this particular investigation, there were 15 patients, or 12 percent, who had symptoms that were suggestive of bleeding. These indications included diverse signal intensities in the areas of infract.Susceptibilityweighted imaging discovered hypointense blooming in the areas of infract in 43 out of 125 patients, which is 34.4% of the total. This study included 82 individuals, and 65.6% of them did not show any signs of hypointense blooming.

Characterization of the hemorrhage by the signal changes seen on T1, T2, FLAIR and SWI was done. The sensitivity and specificity for the detection of hemorrhage by the above sequences was calculated and compared. Hypointense blooming in SWI sequence which is suggestive of hemorrhage was seen in43 (34.4 %) patients. Heterogeneous signal intensity on T2 and FLAIR which is suggestive of hemorrhage was seen in 15 (12%) patients. Hyper intense areas on T1 weighted sequence which is suggestive of hemorrhage was seen in 6 patients (4.8 %). SWI was significantly superior (p value of < 0.004) to the T1, T2 and FLAIR sequences for the detection of the hemorrhage. Use of MR imaging to investigate acute parenchymal and intraventricular hemorrhage in a dog model showed that GRE was more sensitive thanconventional spin-echo T1- and T2-weighted sequences in depicting

hyperacute hemorrhage.[5] Hypointensity on GRE images appeared within 1 hour of hematomaproduction. GRE was also superior to CT in detection of these hemorrhages.[6]
In another study, which compared findings from an animal model with clinical examinations, intracerebral hematoma of less than 24 hours' duration was shown to have a characteristic hypointense rim surrounding variable, heterogeneous hyperintensity on T2-weighted spin-echo images.[7] In this study also areas of heterogeneous signal intensity on T2 and FLAIR sequences were considered as suggestive of hemorrhage. DWI does not seem to be as specific for hemorrhage as itis for ischemic stroke, and the diagnosis of hemorrhage should be based on other sequences. Attempts to measure the apparent diffusion coefficient in ICH are inherently flawed and systematically underestimated since any susceptibility effect will cause dephasing (ie, lower signal intensity) at all b values. Therefore, in an acute ICH, because of the susceptibility effect of deoxyhemoglobin, it would be difficult to measure correctly the apparent diffusion coefficient.[8,9] The spin-echo–type single-shot echo-planar imaging (SE-EPI), turbo spin-echo (TSE)imaging, half- Fourier single-shot turbo spin-echo (HASTE) imaging, and segmented HASTE (s-HASTE) imaging were inferior as compared to SWI sequence for the detection of the chronic hemorrhage.[8] SWI is sensitive for the detection of hemorrhage in hyper acute and chronicstages.The susceptibility sign which is suggestive of acute thrombus was seen in 26 (17.33 %)patients. Acute thrombus is paramagnetic due to the presence of a higher concentration of deoxyhemoglobin which can be readily detected by SWI. Susceptibility sign occurs not only due to the increased paramagnetic effect from deoxyhemoglobin but also due to the increased hematocrit secondary to clot retractionand fibrin formation. Assouline E. et al., reported 88% sensitivity and 100% specificity for MCA and PCA acute occlusion using the gradient echo sequences.[8] Lingegowda et al., reported 82% sensitivity and 100% specificity for the susceptibility sign to detect the arterial occlusion. 10 In this study out of the 21 cases of Susceptibility sign seen, 15 (81.8 %) were seen in the MCA, 3 (16.5 %) in the vertebral artery and 3 (21.0 %) in the venoussinuses. The susceptibility sign was correlated with the time of flight images for MR angiography and MR venography.SWI is sensitive to deoxyhemoglobin, in theory, SWI could detect hemorrhagic transformation as early as several minutes after blood extravasation. Indeed, studies show that SWI can detect hemorrhagic transformation earlier than CT.[10-13] In ourstudy also SWI detected hemorrhagic transformation following intra- arterial thrombolytic therapy in 8 patients, the earliest being within ten hours of treatment.Limited studies have evaluated the utility of SWI in acute stroke patients. Most of the studies done so far had a small sample size in evaluating the useful of SWI. In fact thepresent study may be the first study to assess the utility of SWI in more than 100 cases of acute infarcts.

CONCLUSION

Susceptibility-weighted imaging, also known as SWI, is a relatively new imaging method that was developed to maximise the sensitivity to susceptibility effects. This was accomplished by combining a long TE, fully velocity-compensated 3D gradient-echo sequence with filtered phase information in each voxel. This helped to increase the contrast in magnitude images and added a new source of information, which was the susceptibility difference between tissues. The SWI has a high degree of sensitivity for the detection of bleeding in acute stroke patients. The susceptibility indication is a very helpful indicator in localising the thrombus that is found inside the vessel. The'susceptibility sign' has a high sensitivity for diagnosing acute intracranial vascular blockage in all major intracranial arteries, including the anterior cerebral, middle cerebral, and posterior cerebral arteries, as well as the basilar and vertebral arteries, and the venous sinuses. Because of this, the SWI sequence needs to be incorporated into the procedure for evaluating patients who have recently suffered an acute stroke.

SWI can also be used to test for cerebral bleeding both before and after thrombolytic treatment is administered.

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