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EFFICACY OF SUSCEPTIBILITY-WEIGHTED IMAGING IN DIAGNOSTIC EVALUATION OF ACUTE INFARCTION

Radio-Diagnosis

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ABSTRACT

Introduction: Susceptibility weighted imaging (SWI) is a recent magnetic resonance imaging (MRI) sequence which provides information about any material that has a distinct susceptibility from the structures around it. Traditional MRI is insensitive to microbleeds and petechial hemorrhages in ischemic infarction whereas SWI, a technique used by MRI, is highly sensitive in picking up both. SWI is a T2-weighted gradient echo post-processing reconstruction method that highlights the paramagnetic characteristics of blood components and is extremely sensitive for identifying both extravascular blood components and intravascular venous deoxygenated blood. The aim of our study was to analyse the additional information gathered by SWI over conventional sequences in evaluation of acute infarction. **Materials and methods:** From August 2021 to September 2022, 22 patients with suspected acute stroke were examined prospectively at Sree Mookambika Institute of Medical Sciences, Tamil Nadu using the above sequences. Acute infarct cases were analysed with relevance to additional information derived by inclusion of SWI along with conventional sequences. **Results:** Out of 22 cases of acute infarction on MRI evaluation, 21 cases were arterial infarcts; and one venous infarct. The mean age of cases was 59.82 ± 13.247 years. Minimum age was 34 years and maximum age was 82 years. Among 22 cases of acute infarction, 6 cases (27.3%) showed absent flow void on conventional T2W, in comparison, 10 cases (45.5%) showed susceptibility sign on SWI. Among 22 cases of acute infarction, 3 cases (13.6%) showed blooming within the areas of infarct on gradient (GRE) sequence, in comparison, 7 cases (31.8%) showed blooming on SWI sequence. As compared to GRE sequence, SWI showed higher superiority in detecting larger areas of blooming in the above-mentioned cases. **Conclusion:** SWI can identify even small thrombus/hemorrhage/blood products which may not be apparent on conventional MRI sequences. In hyperacute infarcts rather than depending on absent flow void sign on conventional sequences, Susceptibility sign in SWI sequence is more efficient in localization of intravascular thrombus. Unlike conventional GRE sequence, SWI improves the depiction of lesion and signs with reference to cerebral microbleeds, superficial siderosis, iron deposition and calcification. Therefore inclusion of SWI along with conventional sequences improves the diagnostic efficacy of MR evaluation in acute stroke.

KEYWORDS

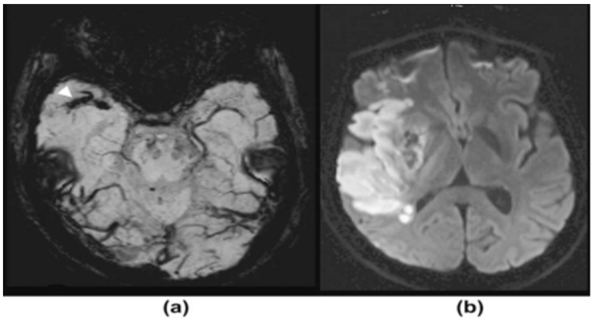
Magnetic Resonance Imaging (MRI), susceptibility weighted imaging (SWI), ischemia, stroke.

INTRODUCTION:

The most common type of stroke is an ischemic stroke, which is brought on by disruption in the cerebral blood flow, which quickly causes energy depletion and cell death. The most effective and proven treatment for acute ischemic stroke (AIS) is thrombolysis, a therapeutic strategy that relies on the idea of the penumbra to restore blood flow in the ischemic area[1,2]. Red thrombus can be easily recanalized following thrombolytic therapy, according to a theory that the type of the thrombus may have an impact on the process[3]. Additionally, the location and size of the thrombus may affect the chosen course of treatment[4]. Despite the fact that intra-vascular thrombus can be detected using digital subtraction angiography (DSA), magnetic resonance angiography (MRA), and computed tomography angiography (CTA), concerns regarding the composition and timing of thrombus formation remain unanswered[4,5].

A technique known as susceptibility weighted imaging (SWI) which can detect hyperacute hemorrhage, is a T2-weighted gradient echo post-processing reconstruction technique that emphasizes the paramagnetic properties of blood components. SWI is incredibly sensitive for detecting both extravascular blood components and intravascular venous deoxygenated blood[3]. According to Kesavadas et al.[6] the raised deoxyhemoglobin-to-oxyhemoglobin ratio increased susceptibility, which resulted in the SWI observation of a conspicuous vein over the damaged cerebral hemisphere.

Intravascular thrombus in SWI manifests as a susceptibility vessel sign (SVS) (fig. 1), an aberrant dark signal with the characteristic look of a thick vessel holding dark signal. A localized increase in deoxy hemoglobin due to red blood cells (erythrocytes) trapped in obstructed arteries is indicated by SVS[3]. Acute or subacute thrombus is encouraged and also the position, multiplicity, and structure of a thrombus can all be learned via SVS. SVS stands for arterial occlusion and is treated with arterial recanalization to resolve the condition[7,8]. We reasoned that susceptibility not only reflects the shape of thrombus but also its time of generation since thrombus synthesis is distinct and only the acute phase of thrombus can demonstrate SVS on SWI.



(a) (b)

Figure 1 The MCA susceptibility sign. (a) Axial SWI image shows acute thrombus in the stem of right MCA with blooming artefact. (b) Diffusion weighted image shows a large acute infarct in the right MCA territory

There are several uses for susceptibility weighted imaging in neuroradiology practice, and it ought to be incorporated into standard protocols. It has the ability to identify cerebral microvasculature, find micro- and macrohemorrhages, and locate low-flow vascular abnormalities. It has been demonstrated to be an advantageous imaging sequence that is complementary for the treatment of stroke patients. It allows for the separation of calcium from brain bleeding. It helps with the grading and characterization of cerebral malignancies as well as the assessment of patients with traumatic brain injuries. By determining the iron concentration of the brain, quantitative susceptibility mapping can be used on a variety of neurodegenerative diseases[9].

Acute stroke can show acute thrombus, deoxygenated blood in veins, and acute hemorrhage, and hence is helpful in stroke evaluation. It increases the conspicuity of hemorrhage nearly sixfold as compared to gradient echo sequences (GRE)[10]. Hence, it should be included as part of routine imaging of the brain in stroke

OBJECTIVE:
To analyse the additional information gathered by SWI over conventional sequences in evaluation of acute infarction.

METHODS:
Study design:
This is a facility based cross sectional study conducted in the department of Radiodiagnosis of Sree Mookambika Institute of Medical Sciences, Kulasekharam, Kanniyakumari, Tamil Nadu.

Study duration:
This study was conducted from August 2021 to September 2022

Study population:
The target population was cases of acute infarcts at Sree Mookambika health facility in the study period.

Selection criteria
Inclusion criteria:
- Patients of all ages and sexes with acute symptoms of stroke in whom MR imaging was done within 7 days showing diffusion restriction with low ADC on MRI.

Exclusion criteria:
- Patients in whom MR imaging was done for all other etiologies other than acute stroke.
- Follow-up MR imaging for patients with chronic stroke or silent episodes of stroke.
- Individuals for whom MR imaging is clinically needed but cannot be done because of a cardiac pacemaker, cochlear implants, or other common MRI contraindications.

Sample size: 22 patients with acute infarcts.

Methodology:
Data collection:
All clinically suspected patients with neurological deficit referred by neurologists, physicians for MRI of brain at Sree Mookambika Institute of Medical Sciences, Kulasekharam, Kanniyakumari, Tamil Nadu.

Equipment:
The machine used in this study was 1.5 Tesla MRI scanner - **conventional sequences + SWI.**

Assess additional imaging findings on SWI.
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 following data was recorded – patient's age, sex, clinical history, territory and type of infarct, extent of infarct, presence or absence of hemorrhage (blooming) in SWI/ GRE along with extent of hemorrhage, presence or absence of T2 flow void, 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.

Data processing and analysis:
Data collected was coded and entered into Microsoft Excel. It was then transferred and analyzed using IBM SPSS version 26 software.

Descriptive statistics:
qualitative data: were presented by frequency tables (Number and percentages).

Quantitative variables:
the normality of data was first tested with Shapiro-Wilk test and presented data by central indices and dispersion: Mean ± Standard deviation (SD) for normally distributed variables. Median and range (Minimum – Maximum) for non-normally distributed variables.

Analytical statistics:
Chi-square test is used to test association between categorical variables. It is replaced by Fisher Exact Test if the expected cell count was less than 5 in four-cells tables, while is replaced by Monte Carlo test if the expected cell count was less than 5 in more than four-cells tables. Association between normally distributed continuous variables was tested using independent sample t-test.

Level of significance:
for all above mentioned statistical tests the results were considered significant when the probability of error is less than or equal 5% ($p \leq 0.05$).

Ethical considerations:
Ethical approval was obtained from the Institutional Human Ethics committee of Sree Mookambika Institute of Medical Sciences.

RESULTS:
Table: 1 Distribution of study participants according to gender

Gender	Frequency (n)	Percentage (%)
Female	8	36.4
Male	14	63.6
Total	22	100.0

Among 22 patients, 14 were male (63.6%) and only 8 were females (36.4%)

Table: 2 Distribution of study participants according to age and gender

Age (in years)	Gender		Total
	Female n (%)	Male n (%)	
30-39	2(9.1)	0(0)	2(9.1)
40-49	1(4.5)	1(4.5)	2(9.1)
50-59	2(9.1)	4(18.2)	6(27.3)
60-69	2(9.1)	4(18.2)	6(27.3)
70-79	1(4.5)	3(13.6)	4(18.2)
more than 80	0(0)	2(9.1)	2(9.1)
Total	8(36.4)	14(63.6)	22(100)

Among the study participants, the peak incidence of neurological deficits was found among males of age group 50-69 years. i.e., 8 patients (36.4 %). The study disease was found most common in females of similar age groups, i.e., 50–69 years old, 4 patients (18.2%). but with a lesser frequency when compared with males.

Table: 3 Distribution of study participants based on territory of acute infarct

Territory of acute infarct	Frequency(n)	Percentage (%)
left ACA and MCA	4	18.2
left MCA	8	36.4
left PCA	1	4.5
right MCA	7	31.8
right PCA	2	9.0
Total	22	100.0

Most of the study participants 8 (36.4%) patients reported acute infarcts in left MCA, while 7 (31.8%) reported in right MCA, 4 (18.2%) in left ACA and MCA, 2(9%) in right PCA and only 1(4.5%) in left PCA.

Table: 4 Distribution of signal intensity pattern on T1 weighted imaging

Conventional T1W1/FLAIR	Frequency (n)	Percentage (%)
ISOINTENSE	18	81.8
HYPERINTENSE	3	13.6
HETEROINTENSE	1	4.5
Total	22	100

Among 22 patients with acute infarcts, 3 (13.6%) showed hyper intensities on T1W which showed blooming on SWI suggestive of hemorrhagic product which excludes incomplete infarction.

Table: 5 Distribution based on T2 weighted imaging of acute infarcts

Conventional T2W1	Frequency (n)	Percentage (%)
Flow void present	16	72.7
Absent flow void	6	27.3
Total	22	100.0

T2 weighted imaging showed absent flow void in 6 cases (27.3%) suggestive of intraluminal thrombosis.

Table: 6 Distribution of thrombosis based on susceptibility sign

Susceptibility sign in SWI	Frequency (n)	Percentage (%)
ABSENT	12	54.5
PRESENT	10	45.5
Total	22	100.0

SWI sequence showed susceptibility sign in the 10 cases (45.5%) showed suggestive of intraluminal thrombus.

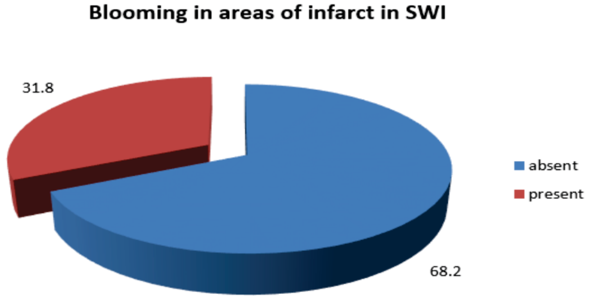


Figure: 1 Pie chart depicting percentage of hemorrhagic transformation

7 cases (31.8%) showed blooming within the areas of infarct on SWI sequence suggesting of acute infarct with haemorrhagic transformation.

Table:7 Distribution pattern of 7 cases of hemorrhagic transformation (SWI vs GRE)

Cases with heamorrhagic transformation	Blooming in GRE	SWI	
		Blooming	Areas of blooming
1	Present	Present	• GRE
2	Absent	Present	
3	Present	Present	• GRE
4	Absent	Present	
5	Absent	Present	
6	Absent	Present	
7	Present	Present	• GRE

Among 22 cases of acute infarction, 3 cases (13.6%) showed blooming within the areas of infarct on gradient (GRE) sequence, in comparison, 7 cases (31.8%) showed blooming on SWI sequence. As compared to GRE sequence, SWI showed higher superiority in detecting larger areas of blooming in the above mentioned cases

DISCUSSION:

Susceptibility-weighted imaging (SWI) is a novel method that uses variations in tissue susceptibility to provide a unique kind of tissue contrast. Because of its intrinsic sensitivity, improved spatial resolution, and thinner collected slices, it is even more sensitive to blood products than the gradient-echo (GRE) technique[9]. The results of this study showed that the age range of 50 to 69 years old, which included 8 patients, had the highest frequency of neurological abnormalities among males (36.4 %). In this study, there were 22 people in total, 8 of whom had just hypertension (representing 36% of the population), and 14(63.6%) of whom had no history of hypertension at all.

According to this study, none of them had more than one comorbidities and 5 patients (22.7%) did not previously have either hypertension or diabetes mellitus or cardiac disease. Three of the seven patients with hemorrhagic infarcts, or 13.6 percent of the total, had hypertension, while one of the 7 patients with hemorrhagic infarcts, or 4.5% of the total, had diabetes mellitus. 7 people had hemorrhage, with 6 cases being arterial infarcts and 1 being venous infarcts, as seen in [Table 9]. 4 (57.1%) out of 14 male patients and 3 (42.9%) out of 8 female patients both experienced hemorrhage.

Out of 22 patients in this study, 21 cases (95.5%) had arterial infarct and 1 case (4.5%) had venous infarct. Susceptibility sign in SWI, which denotes the presence of an intravascular thrombus, was noted in 10 patients (45.5%) in comparison to absent flow void in T2WI in 6 cases (27.3%). Blooming within the areas of infarct suggestive of hemorrhagic transformation was noted in only 3 cases (13.6%) on gradient (GRE) sequence, in comparison, 7 cases (31.8%) showed blooming on SWI sequence.

SWI was able to identify older microbleeds that were undetectable by CT, T1, or T2/FLAIR imaging. This was in accordance with Santhosh et al[11] and Mittal et al[12], who stated that SWI, with its superior sensitivity, finds several microbleeds that are undetectable on any standard imaging. The findings of **Charidimou et al**.[13] backed up the notion that cortical microbleeds in ischemic stroke patients were a radiological indication for more serious and potentially progressive small artery pathology, requiring active therapy, including good control of blood pressure and other vascular risk factors.

Our work was in line with that and revealed a significant prevalence of microbleeds. This finding may be explained by the SWI image's superior sensitivity to traditional T2* imaging, particularly on 1.5 Tesla magnets. According to **Cordonnier et al**[16] and **Nandigam et al**[17] microbleeds prevalence in patients with cerebrovascular diseases ranged from 41.6% when using a 1.0 T magnet to 46.9% when using a 1.5 T magnet. SWI has recently been shown to detect 67% more cortical microbleeds than conventional GRE T2* sequence, according to **Cordonnier et al**[16]. Within an hour of the hematoma's formation, hyperpointensity on GRE pictures became visible. Additionally, GRE outperformed CT in identifying these hemorrhages[18].

The susceptibility sign also results from an increased hematocrit as a result of clot retraction and fibrin production, in addition to the increased paramagnetic influence of deoxyhemoglobin. Using gradient echo sequences, **Assouline E. et al**[20]. showed 88% sensitivity and 100% specificity for MCA and PCA acute occlusion. According to **Lingegowda et al**[21]., the susceptibility sign has a 100% specificity and an 82% sensitivity for detecting arterial occlusions.

From the 10 cases of susceptibility signs that were seen in this study, 6 (60%) were found in the MCA, 3 (30%) in the ICA, and 1 (10%) in the venous sinuses. Since SWI can identify hemorrhagic transformation as soon as several minutes after blood extravasation due to its sensitivity to deoxyhemoglobin[15,21,22]. Studies do indeed support the claim that SWI can identify hemorrhagic change before CT.

CONCLUSION:

SWI can identify even small thrombus/hemorrhage/blood products which may not be apparent on conventional MRI sequences. In hyperacute infarcts rather than depending on absent flow void sign on conventional sequences, Susceptibility sign in SWI sequence is more efficient in localization of intravascular thrombus. Unlike conventional GRE sequence, SWI improves the depiction of lesion and signs with reference to cerebral microbleeds, superficial siderosis, iron deposition and calcification. Therefore inclusion of SWI along with conventional sequences improves the diagnostic efficacy of MR evaluation in acute stroke.

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