Original Research Article

Reliability in detection and differentiation between calcification and hemorrhage by 3 d GRE/ SWI technique compared to CT

Monica Gunasingh[1], Praveen Sharma[2*], Muthiah Pitchandi[3], Karthik Krishna Ramakrishnan[4], Yuvaraj Muralidharan[5]

[1]Research Scholar, Department of Medical Imaging Technology, Saveetha College of Allied Health Sciences, Saveetha University, Thandalam, Chennai, Tamil Nadu, India
[2]Associate Professor, [3]Professor, [4]Assistant Professor, [5]Associate Professor,
Department of Radio-Diagnosis, Saveetha Medical College and Hospital, Saveetha University, Thandalam, Chennai, Tamil Nadu, India
[*]Corresponding author email: **kpraveensharma.kps@gmail.com**

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Abstract

This study was conducted to evaluate the sensitivity of Magnetic Resonance (MR) Susceptibility-Weighted Imaging (SWI) and also to compare the sensitivity of Magnetic Resonance (MR) susceptibility-Weighted Imaging (SWI) and Computed Tomography (CT), such that SWI can replace the use of CT as a standard protocol in the detection and differentiation between calcification and hemorrhage. A series of 70 patients included in this study with clinical suspicion or known history of intracranial hemorrhage/ calcifications for follow up, were scanned using both Philips Multiva 1.5T (MRI/SWI) and Philips Ingenuity 128 slice (CT). Results showed that SWI had 100% relative sensitivity, as it was able to detect both hemorrhage and calcifications in all the cases identified in CT. In addition, SWI detected hemorrhage in 2 additional cases that were nonspecific in CT. Furthermore, SWI detected signal from micro bleeds, which was missed on CT in three cases, and also detected calcification in two cases, which were not positively identified in CT. In conclusion, Susceptibility-Weighted Imaging (SWI) is highly sensitive for the detection and differentiation of hemorrhage and calcifications using Phase reconstructed images compared to conventional MRI methods and Computed Tomography.

Key words

Susceptibility- Weighted Imaging, Hemorrhage, Calcifications.

Introduction

Magnetic resonance imaging (MRI) is an imaging technique that produces an image based on relaxation properties of tissues. It is a modality that does not employ any form of ionizing radiation. Although MRI is mainly used for its superiority in soft tissue contrast, the relaxometry-weighted images are not definitive in the differentiating hemorrhage and calcifications as both the paramagnetic and diamagnetic atoms of hemorrhage and calcification respectively, reduce the relaxation times of the tissue due to in homogeneity [1]. Traditionally, both blood products and calcifications which appear to be hypo intense in the MRI gradient imaging sequences [2] were imaged using Computed Tomography for aiding the diagnoses. So, to find the probable cause of hypo intensity, in clinical practice, Computed Tomography is considered to be the conclusive imaging technique. This was performed at the cost of radiation dose due to exposure to ionizing radiation in CT. Moreover, this took a rather long imaging time and patient strain as they had to be shifted from one imaging modality to another.

Magnetic susceptibility is defined as the way a substance behaves under the influence of the magnetic field, in other words, the response of a substance to an externally applied magnetic field [3]. Diamagnetic substances, for example, calcium, have magnetic susceptibility less than 0, Paramagnetic substances, which includes iron-based compounds, such as hemosiderin, have magnetic susceptibility greater than 0 [4].

Susceptibility-weighted imaging (SWI) reconstructs images combining both the information from phase and magnitude images [4], whereas conventional MRI methods use only the magnitude data thus eliminating the phase information. As the susceptibilities of calcium and iron are at opposite extremes, they result in opposing phase values on the phase images [4] such that the displayed image showed a vast difference between hemorrhage and calcification [5] , hyper intense and hypo intense respectively, which was not seen in conventional MRI images.

This study evaluates Susceptibility-Weighted Imaging and CT in the detection and differentiation between calcification and Hemorrhage, hence providing useful data to compare the sensitivity of both modalities, such that the appropriate modality can be chosen for aiding the diagnosis, which utilizes the least possible radiation dose while maintaining reliability. The appropriate protocol selection will in turn be a benefit for future patients.

Materials and methods

A prospective study was conducted in Department of Radiology, Saveetha Medical College and Hospital from April, 2019 to April, 2020. Data was collected from around 70 patients referred for investigational procedures with clinical suspicion or known history of intracranial hemorrhage/ calcifications for follow up.

Magnetic Resonance Imaging/ Magnetic Resonance Susceptibility-Weighted Imaging were performed using PHILIPS MULTIVA 1.5 TESLA MRI. The Magnetic Resonance Imaging protocol, were planned using a 3 Plane Localizer, including routine brain protocol (Diffusion-Weighted Imaging sequence, Inversion Recovery T2W (FLAIR), T1W Spin Echo, T2W Turbo Spin Echo, Axial T2W Fast Field Echo) and the Gradient recalled echo-Susceptibility Weighted Imaging sequence. The SWI acquisition time was about 3 minutes 37 seconds. SW images were created using both the magnitude and phase raw data sets.

The three dimensional (3D) gradient SWI technique has been previously known as MR venography [6] and high-resolution BOLD venography [7]. The sequence is a T2*-weighted 3D Fast Field Echo sequence (TR/TE: 51/12 msec, Flip Angle 20°), with flow compensation in all three principal orthogonal directions. Twenty- four slices of 2 mm were acquired, using a field of view (FOV) of 230 × 187 × 130 (AP × RL × FH) and a Voxel Size of 0.99 × 1.14 × 2.00 (AP × RL × FH).Finally, a minimum intensity projection is performed to display the processed data in the axial plane. The processing was done automatically within the Philips software.

Computed Tomographic evaluation was performed using Philips Ingenuity 128 Slice CT scanner. Automatic exposure control was activated, and using a Dual Scout localizer, the scan sections were planned parallel to the orbitomeatal baseline, with FOV covering the brain from base of the skull to vertex using 1mm acquisition and Window Width/ Window Level of 80/ 40. Bone plus reconstruction algorithm was activated (Window Width/ Window Level: 2000/ 800).

The Gray scale CT and MRI/SWI (magnitude and phase corrected) images were visually assessed, with CT as a reference for the presence of hemorrhage and calcification.

Results

In this study, the maximum numbers of patients were Male (71%). 29% of patients were Female. Out of 70 cases, 38 cases were found to be hemorrhagic, 22 cases calcific, and 2 cases with both calcification and hemorrhage. 8 cases were of various presentations such as Ischemic infarction, Parkinson’s disease (**Table - 1**).

The total number of hemorrhagic findings were 40, out of which 40% of the hemorrhage was related to the vasculature (Cavernoma, micro bleed, and malformation), 30% were hemorrhagic infarct, 15% were of tumor related hemorrhage (acoustic Schwannoma), 10% were trauma related hemorrhage, and 5% were hypertensive hemorrhage (**Table - 2**).

Table - 1: Distribution of pathology.

Type	No. of cases	Percentage
Hemorrhage	38	54%
Calcification	22	31%
Mixed	2	3%
Others	8	12%
TOTAL	70	100%

Table - 2: Classification of hemorrhage.

Type	No. of Cases	Percentage
Trauma	4	10%
Tumor	6	15%
Hypertensive	2	5%
Vascular	16	40%
Hemorrhagic Infarct	12	30%
TOTAL	40	100%

Table - 3: Classification of calcification.

Type	No. of Cases	Percentage
Infection	13	54%
Tumor	6	25%
Physiological- Age related	5	21%
TOTAL	24	100%

The total number of calcific findings were 24, out of which 54% of the Calcification were found to be tumorous (meningioma, granuloma, Cavernoma and acoustic Schwannoma), 25% were infectious (Neuro cystic Cirrhosis, tuberculosis and granulomatous infection), and 21% were age-related physiological calcifications (**Table - 3**).

SWI showed 100% relative sensitivity, as it was able to detect both hemorrhage and calcifications in all the cases identified in CT (**Image – 1**).

In addition, SWI detected hemorrhage in 2 additional cases that were not positively identified in CT. In the two patients with chronic infarct (as shown in **Image - 2**), SWI demonstrated susceptibility effects in the magnitude reconstructed image. The corresponding phase image showed negative susceptibility effects (regions of hypo-density), consistent with findings of hemorrhage.

SWI is highly sensitive in detecting signal from micro bleeds, which was missed on CT, and detected hemorrhage in three cases (**Image - 3**) and calcification in two cases, which were not positively identified in CT.

Image - 1: 29-year-old male, Known case of Neurocysticercosis. (A) NECT showed well-defined round hyper-dense calcific focus in the left frontal lobe. (B) T2*W Gradient blooming noted corresponding to the area seen in NECT (C) SWI Magnitude image showed hypo-intense focus (D) The Phase image appears calcific. The findings were suggestive of calcified Granulomatous focus, possibly infective- Neurocysticercosis.

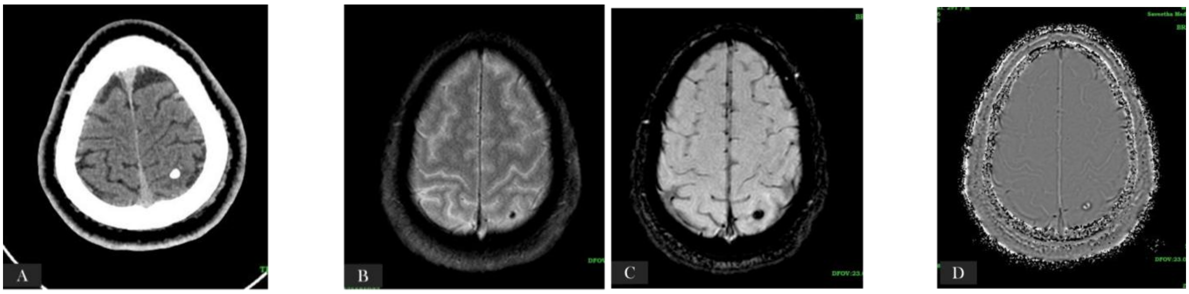


Image - 2: 45 -year-old male (A) NECT showed an area of subtle altered density in the left cerebellar hemisphere, appearing non-specific on CT (B) T2*W Gradient blooming noted corresponding to the area seen in NECT (C) SWI Magnitude image showed susceptibility effects, (D) and appears hypo-intense on the Phase image, suggestive of early hemorrhagic transformation- luxury perfusion.

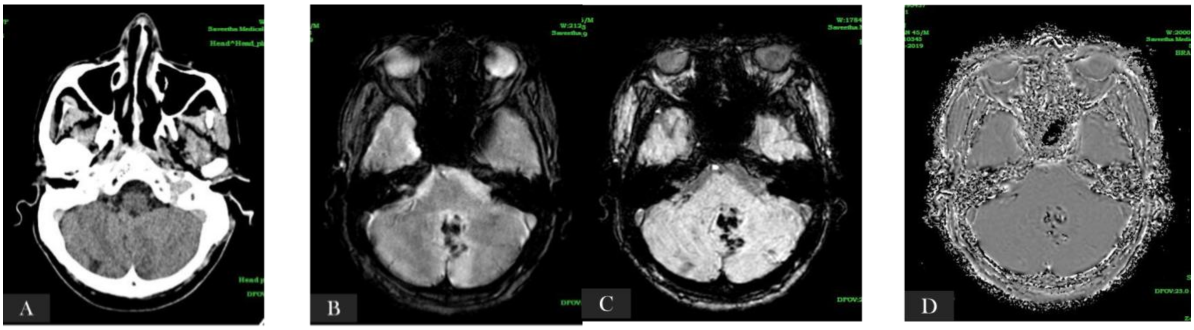
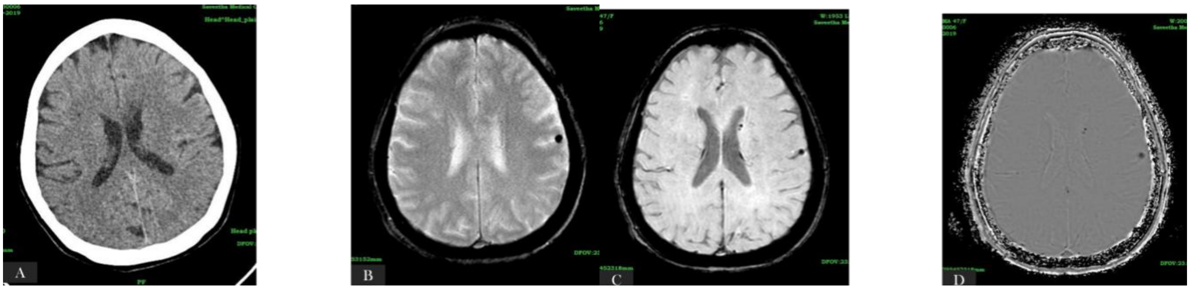


Image - 3: 47 -year-old female (A) NECT showed areas of ill-defined hypo-density scattered diffusely in the neuro parenchyma, appearing non-specific on CT (B) T2*W Gradient blooming noted corresponding to the area seen in NECT (C) SWI Magnitude image showed susceptibility effects, (D) and these areas appear hypo-intense on the Phase image, suggestive of micro bleeds.



Discussion

A prospective study was conducted with70 patients, the maximum numbers of patients being Male (50 patients) constituting 71%of the study population. 29% of patients were Female. Patients with clinical suspicion of intracranial hemorrhage/ calcifications and patients with history of intracranial hemorrhage/ calcifications were included. The patients were scanned using both Philips Multiva 1.5T (MRI/SWI) and Philips Ingenuity 128 slice (CT) after detailed explanation on the procedure and previous medical records and informed written consent were obtained. Magnetic Resonance Imaging/ Magnetic Resonance Susceptibility-Weighted Imaging were performed using PHILIPS MULTIVA 1.5 TESLA MRI. First, conventional MRI protocol was performed, followed by SWI sequence. The phase maps were auto-generated by the software, and displayed as a grey-scale image, for visual assessment. Computed Tomographic evaluation was performed using Philips Ingenuity 128 Slice CT scanner. Images were reconstructed in thin slices with the helical data, acquired in the axial plane.

Out of 70 cases, 38 cases were found to be hemorrhagic, 22 cases calcific, and 2 cases with both calcification and hemorrhage. 8 cases were of various presentations such as Ischemic infarction, Parkinson's disease (**Table - 1**).

Using CT as the norm for detecting blood products and calcifications, SWI showed 100% relative sensitivity, as it was able to detect both hemorrhage and calcifications in all the cases identified in CT (refer **Image - 1**). In addition, SWI detected hemorrhage in 2 additional cases that were not positively identified in CT. In the two patients with chronic infarct, SWI demonstrated susceptibility effects in the magnitude reconstructed image. The corresponding phase image showed negative susceptibility effects (regions of hypo-density), consistent with findings of hemorrhage (as seen in **Image - 2**). This study was performed in a right handed reference system. Therefore, calcifications appear hyper-intense on the phase image, whereas blood products appear hypo-intense.

These findings were similar to that demonstrated by Nathaniel D. Wycliffe, et al, in a study conducted in 2003 [7]. Since SWI is comparatively more sensitive than CT in the detection of a hemorrhage, it would be beneficial to use SWI to also exclude the presence of acute hemorrhage within an infarct [8], or to differentiate between an ischemic infarct from a hemorrhagic one.

Susceptibility-weighted imaging (SWI) combines the information from phase and magnitude images [3]. The signal intensity change observed are based on both T2* dephasing and susceptibility differences between tissues [4]. Normally, images that are displayed in MRI are reconstructed using magnitude reconstruction, that is, only with the magnitude data. The phase of the MR signal is irrelevant. Hence, pixel brightness depends only on the magnitude of a tissue's longitudinal magnetization, not its phase. In other words, two tissues whose magnetization at echo collection time TE point is equally dephased but opposite with susceptibly effects will be assigned the same shade of gray, as both have decreases the signal intensity, and in turn be indistinguishable.

Diamagnetic substances, for example, calcium, have magnetic susceptibility less than 0, Paramagnetic substances, which includes iron-based compounds, such as hemosiderin, have magnetic susceptibility greater than 0[4].The magnetic susceptibilities of hemorrhage and calcification cause small variations in the main magnetic field, which then influence the phase of the MR signal [9]. Because the susceptibilities of calcium and heme iron are at opposite extremes, they result in opposing phase values on unwrapped phase images [4].

SWI is highly sensitive in detecting micro bleeds, which was missed on CT (**Image - 3**).

SWI detected hemorrhage in three cases and calcification in two cases, which were not positively identified in CT. The blood and calcific products, which were volume averaged with the normal brain parenchyma in CT, caused T2* dephasing in the magnitude image, hence appearing hypo intense. It was confirmed to be micro bleed as it was hypo intense in the unwrapped phase images. These results matched the description based on the study conducted by Jatta Berberat, et al. in 2003 [4].

CT is the most commonly used modality to detect the presence of calcification and hemorrhage, but, volume averaging results in attenuation values of micro hemorrhages and calcifications to be averaged with the surrounding normal brain parenchyma [10]. This leads to false negative prediction, hence making it less reliable for the detection of micro hemorrhages and calcifications. Reduction in the slice thickness by manipulating the parameters such as pitch, results in an increase in the radiation dose significantly, with no or very less probability and assurance of increased diagnostic accuracy.

From the results of this study, it is established that SWI is highly sensitive for the detection and differentiation of hemorrhage and calcifications using Phase reconstructed images. These results match with the results of Berberat, et al. [4] and Wycliffe, et al. [7]. Phase imaging is proved to be more sensitive than conventional MRI sequences and CT. Therefore susceptibility phase images should be used to strengthen the detection of calcification and hemorrhage.

Although the SWI technique was originally invented to enhance visibility of veins [6], most of the small vessels are easily differentiated from hemorrhages by their homogeneous curvilinear pattern. This can be further aided by use of the post-processing method, minimum intensity projection, which combines two adjacent 2-mm slices into a final 4-mm image. Several contiguous images are viewed to trace and follow a vessel.

Limitations

The current scan time using SWI is about 3-5 minutes for 24 2-mm slices which is rather long. An improvement in speed can be seen by utilizing segmented EPI or with parallel imaging techniques. With these new methods, faster imaging times, along with greater volume coverage are possible.

Conclusion

In conclusion, Magnetic Resonance (MR), Susceptibility-Weighted Imaging (SWI) is highly sensitive for the detection and differentiation of hemorrhage and calcifications using Phase reconstructed images.

Phase imaging is proved to be more sensitive than conventional MRI sequences and CT. Therefore susceptibility phase images should be used to strengthen the detection of calcification and hemorrhage, such that SWI can replace the use of CT as a standard protocol in the detection and differentiation between calcification and Hemorrhage.

Abbreviations

MRI	-	Magnetic Resonance Imaging
CT	-	Computed Tomography
FOV	-	Field Of View
TR	-	Repetition Time
TE	-	Echo time
SWI	-	Susceptibility weighted Imaging
EPI	-	Echo Planar Imaging

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