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Analysis Data Obtained from Susceptibility Weighted Imaging for Evaluation of Hemorrhage, A Comparison with Gradient Echo Sequence in MRI-A Prospective Study

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Abstract

Introduction: Magnetic Resonance Imaging (MRI) plays a vital role in detecting intracranial hemorrhage due to its superior soft tissue contrast and sensitivity. Among MRI sequences, Gradient Recalled Echo (GRE) has been widely used; however, Susceptibility Weighted Imaging (SWI) is a more advanced technique that enhances visualization of hemorrhagic lesions and microbleeds by exploiting magnetic susceptibility differences.

Objective: To evaluate the effectiveness of SWI in detecting intracranial hemorrhage and compare its diagnostic performance with GRE sequences using both manual and automated measurement methods.

Methodology: A hospital-based prospective study was conducted on 25 patients with clinically suspected brain hemorrhage. MRI scans were performed using a 1.5 Tesla system. GRE and SWI sequences were analyzed. Hemorrhage areas were measured manually and automatically using ImageJ software. Statistical analysis, including paired t-tests, was performed to compare sensitivity and measurement accuracy.

Results: SWI demonstrated higher detection rates compared to GRE. In trauma cases, detection was 100% (17/17) with SWI versus 92% (16/17) with GRE. For amyloid cases, SWI detected 100% (4/4), while GRE detected 0%. Mean hemorrhage area (manual) was lower in SWI (5.32 ± 4.09 sq.cm) than GRE (7.70 ± 5.64 sq.cm). Automated measurements showed improved sensitivity. Statistical analysis revealed significant differences ($p = 0.00$ for manual GRE vs SWI; $p = 0.0006$ for automated comparison).

Conclusion: SWI is significantly more sensitive and reliable than GRE in detecting intracranial hemorrhage and microbleeds. Automated measurement methods further enhance diagnostic accuracy, supporting SWI as a preferred imaging technique in neuroimaging.

Keywords: MRI, Susceptibility Weighted Imaging, Gradient Echo, Intracranial Hemorrhage,

1. Introduction

Magnetic resonance imaging (mri) is a non-invasive imaging modality that utilizes strong magnetic fields and radiofrequency (rf) pulses to generate high-resolution images of anatomical structures and physiological processes. Unlike computed tomography (ct), mri does not involve ionizing radiation and offers superior soft tissue contrast, making it particularly valuable in neuroimaging. The technique relies on the behavior of hydrogen protons within tissues, which, when subjected to an external magnetic field and rf excitation, emit signals that are processed to produce detailed cross-sectional images.

Intracranial hemorrhage (ich) is a critical neurological condition that may arise due to trauma, vascular abnormalities, hypertension, anticoagulant therapy, or aneurysmal rupture. Early and accurate detection of hemorrhage is essential for appropriate clinical management and improved patient outcomes. While ct remains the first-line modality for acute hemorrhage detection due to its rapid acquisition and accessibility, mri provides greater sensitivity and specificity, particularly in subacute and chronic stages, as well as in the detection of microhemorrhages.

Among mri sequences, gradient recalled echo (gre) t2*-weighted imaging has traditionally been used for detecting hemorrhagic lesions. Gre sequences are sensitive to magnetic susceptibility effects caused by paramagnetic substances such as deoxyhemoglobin, hemosiderin, and ferritin. These substances create local magnetic field inhomogeneities, resulting in signal loss that appears as hypointense regions on images. Gre imaging is particularly useful in identifying hemorrhagic stroke, cerebral microbleeds, and diffuse axonal injury. However, its sensitivity may be limited in detecting very small or subtle hemorrhagic lesions.

Susceptibility weighted imaging (swi) is an advanced three-dimensional mri technique that enhances susceptibility contrast by combining both magnitude and phase information. This sequence amplifies the effects of local magnetic field variations, thereby improving visualization of blood products, venous structures, and microhemorrhages. Swi is highly sensitive to paramagnetic substances and can detect lesions that may not be visible on conventional gre imaging. Additionally, swi provides improved spatial resolution and allows for better characterization of hemorrhagic components, making it particularly useful in conditions such as traumatic brain injury, vascular malformations, cerebral amyloid angiopathy, and hemorrhagic tumors.

Cerebral microbleeds (cmbs) are small, round or ovoid hypointense lesions seen on susceptibility-sensitive mri sequences, representing focal deposits of hemosiderin. These lesions are clinically significant as they are associated with various cerebrovascular disorders, including hypertensive vasculopathy and cerebral amyloid angiopathy, and may have prognostic implications in stroke and dementia. Accurate detection of these microbleeds is therefore crucial, and swi has been shown to outperform gre imaging in this regard.

Despite the advantages of swi, gre sequences remain widely used due to their shorter acquisition time and availability across mri systems. Therefore, a comparative evaluation of swi and gre sequences is essential to determine their relative effectiveness in detecting intracranial hemorrhage and microhemorrhages.

The present prospective study aims to analyze data obtained from susceptibility weighted imaging for the evaluation of intracranial hemorrhage and to compare its diagnostic performance with gradient recalled echo sequences. Additionally, the study seeks to assess the detection of cerebral microbleeds using both manual and automated methods, including region-of-interest (roi) analysis with imagej software. By establishing the relative sensitivity and accuracy of these imaging techniques, this study intends to contribute to improved diagnostic strategies in neuroimaging of hemorrhagic conditions.

Materials and methodology: Data is collected in the year of 2018 – 2019 from the department of radiology, chri.

Study design: Hospital based descriptive and prospective study.

Sample size: 25 patients were included in this study.

Sampling technique: Simple random technique was used for this study

Selection criteria: A patients historyof traumaand non- traumatic symptomsof high blood pressure, sudden & severe head ache, loss of balance or coordination

Inclusion criteria: Patients with hemorrhage in brain who undergone MRI

Exclusion criteria

- Patients on metallic implants and
- cardiac pacemakers
- claustrophobic patients

Machine used: A 1.5 tesla signa GE MRI scanner was used to scanner the patients with a8 channel nv (navigator) radiofrequency coil was used. The bore size of the machine is 60cm.

Fig .11 a MRI scanner

Fig .12 b: MRI head coil 16e head neck array coil

The coil acts as an antenna to receive the radio frequency signal coming out of your body and transmit that data to a computer which then generates images.

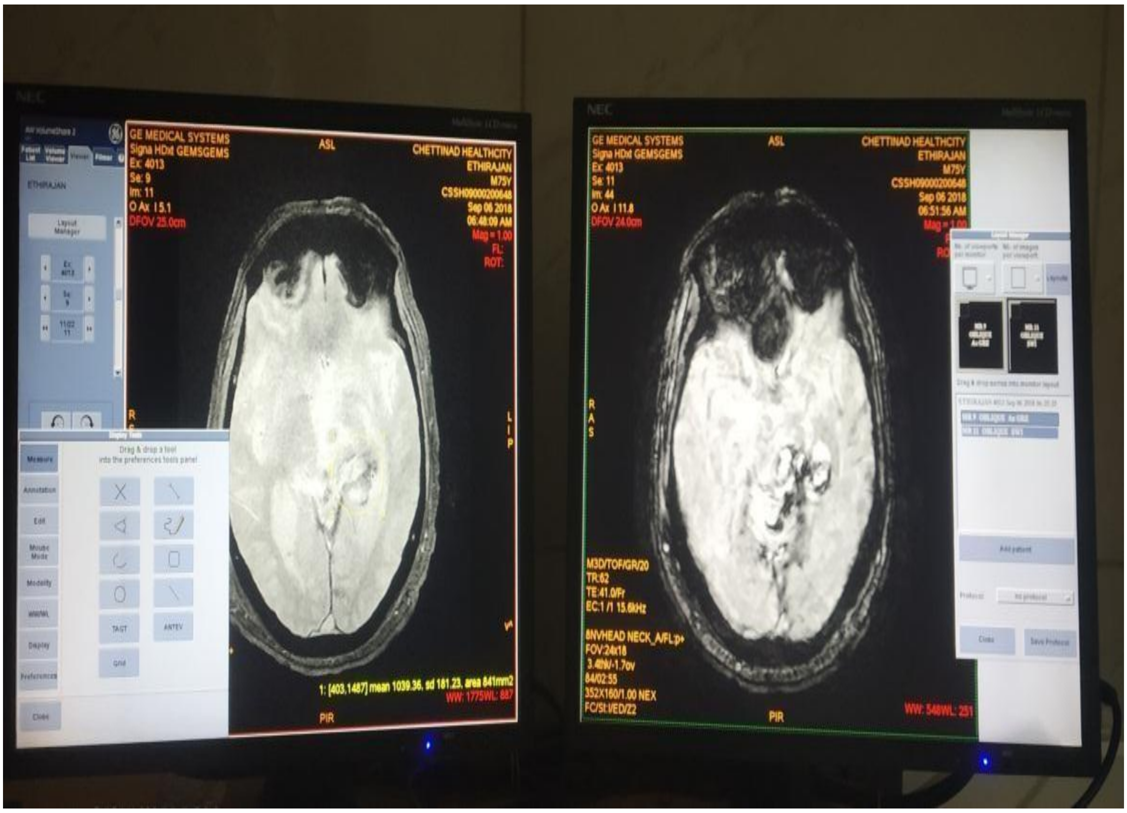


Fig. 13 MRI work station (adw)

Data analysis

The images acquired for this study was analyzed on specific objectives. The axial section of the brain image of swi and gre images of 25 patients is obtained and analyzed using imagej (nih software package) and the area of hemorrhage was marked manually in the work station and automatically by using imagej package and threshold technique. The calculated areas were used further for descriptive analysis using spss software.

Ethical consideration

The research proposal was approved by the institutional human ethical committee of the chettinad academy of research and education.

Examination technique and MRI sequences

Patients were undergone the following routine brain sequences like

- Dwi (diffusion weighted imaging)
- T2 axlflair
- T1 axl flair
- Axlgre(gradient recalled echo)
- T2 cor flair
- T1 sag flair
- Swi (susceptibilityweightedimage)
- Dti (diffusion tensorimaging)
- Axl t1 fat sat (precontrast)

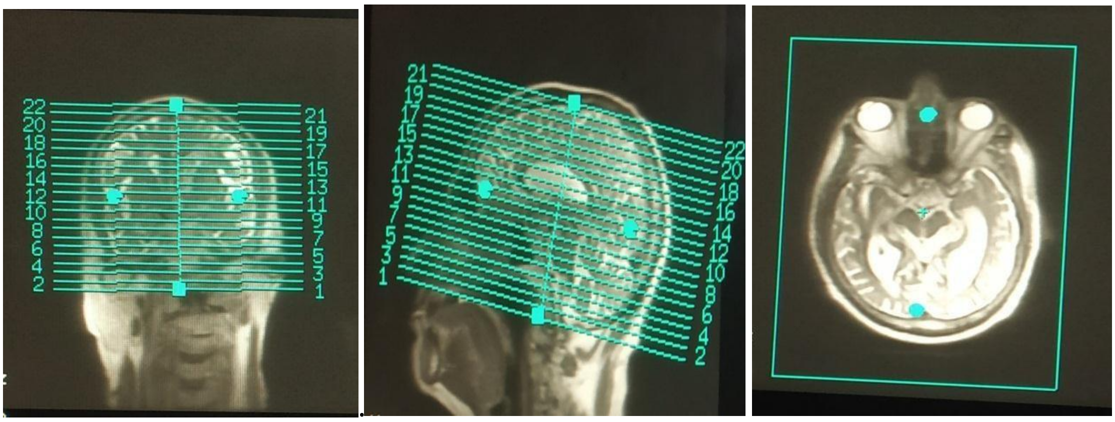
- Axl t1 fat sat(postcontrast)
- Coronal t1 fatsaturation
- Sagittal t1 fatsaturation

Image planing

Sequence is planned based on the three plane localizer, which is obtained initially.

Mri acquisition plan for gre-sequence

Coronal plane sagittal plane axial plane



Coronal plane sagittal plane axial plane

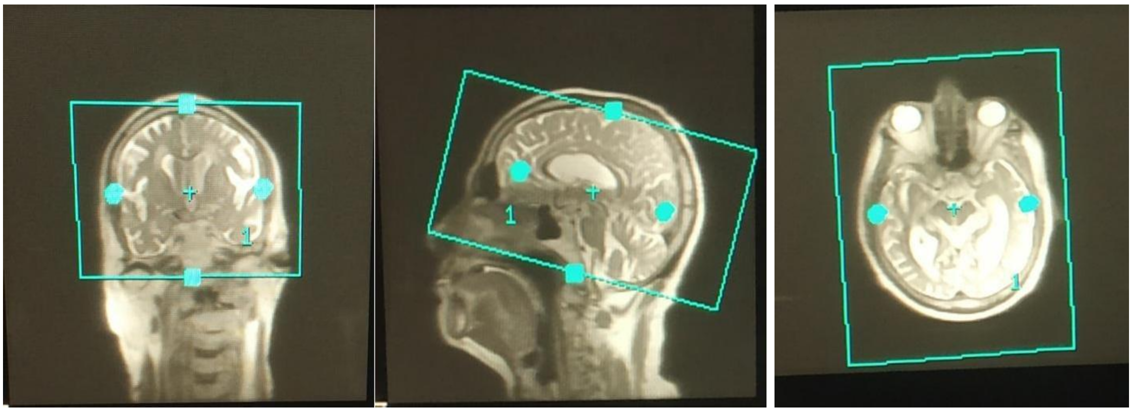


Fig.15. Plan for swi-seque

Image acquisition parameter

Parameters used for the acquisition for the mri sequence.

Table.1

Parameter	Gre	Swi
Mode of acquisition	2d	3d
Plane	Axial	Axial
Fov (mm)	24	24
Tr	500	62
Te	15	41
Matrix	512*224	352*224
Fatsat	No	No
Slice thickness(mm)	5	3
Inter slice (mm)	1.5	-
Nex	1	1
Timing (min)	1.28	3.28
Iv contrast	No	No

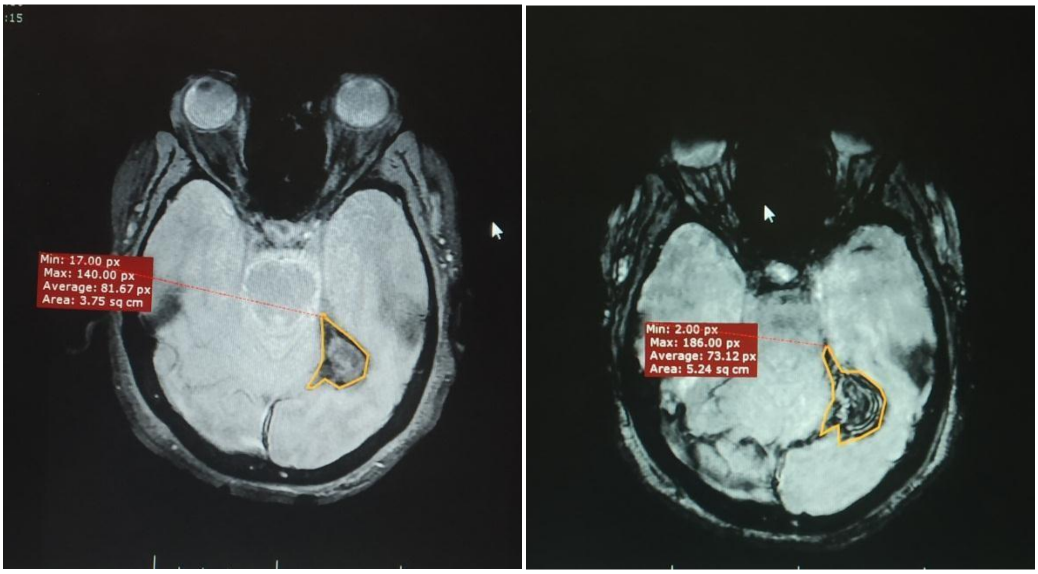
Research methodology& results

In the present study, 25 patients with clinical diagnosis of brain hemorrhages were referred for mr imaging in chettinad hospital and research institute, kelambakkam.

The mri was performed in ge 1.5 tesla scanner with 8 channel head coil. All the routine sequences and additionally done with swi sequence. Then analysis data obtained from swi and gre sequence.

Step:1

- Areas are measured from the slices which show greater hemorrhages in gre and swi sequence.
- The areas of hemorrhage are manually drawn and calculated in sq.cm**(fig.8)**



Gre Swi

Fig.4 .manual measurement of hemorrhage

step:2

- Areas are measured from the slices which show greater hemorrhages in gre and swi sequence
- The areas of hemorrhage are automatically measured and calculated

  Using image software the areas of hemorrhage are cropped and converted into the binary image and then threshold to measure the area of bleed.
- The area of measurements are calibrated with mri work station and converted to square centimeter (sq cm)

Orginal image cropped image cropping roi

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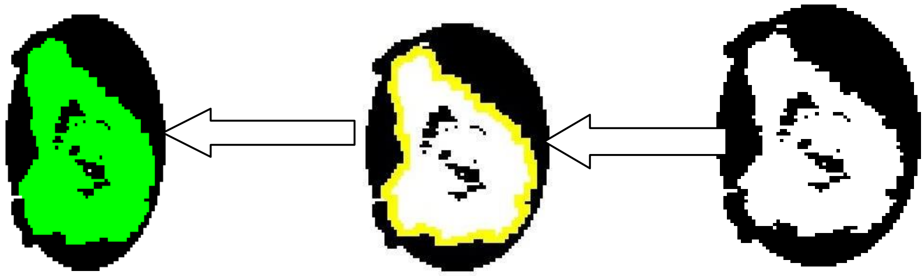
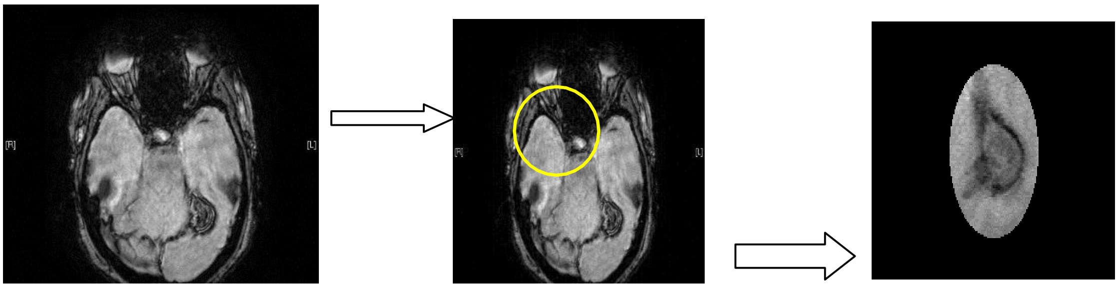
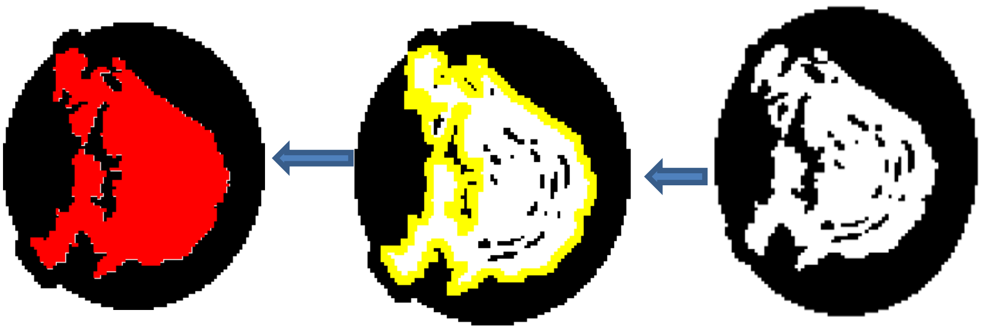


Color coded image threshold image binary image

Fig.15a gre –process of areas measurement



Orginal image cropping roi cropped image



Color coded image threshold image binary image

Fig.15b.swi –process of areas measurements

Step -3 table.2

Clinical condi-tions	Hemorrhage detect-ed%	Hemorrhage detect-ed%	Area of hemorrhage			
			Manual (roi gre).sq.cm	Manual (roi swi). Sq.cm	Automated (roi gre).sq.cm	Automated (roi swi). Sq.cm
Trauma	16/17=92%	17/17=100%	7.70 ±5.64	5.32 ± 4.09	9.42 ±6.49	7.42±5.32
High bp	4/4=100%	4/4=100%	1.73 ±0.47	1.21 ± 0.79	2.71 ±0.94	1.84±1.42
Amyloids	0/4=0%	4/4=100%	-	-	0.38 ±0.152	0.3 ± 0.12

The values of mean, standard deviation of manual and automated methods(astab.2)

Table. 3.

The measured mean areas were compared using student t-test (paired) and p-values are displayed in the table shown below (table-3) comparing the manual gre,manual swi, automated gre and automated swi (for sequence sensitivity) .manual gre, automated gre, manual swi and automated swi (for sensitivity of cropping methods).

Method		P-value
Manual gre	Manual swi	0.00
Automated gre	Automated swi	0.0006
Manual gre	Automated gre	0.027
Manual swi	Automated swi	0.012

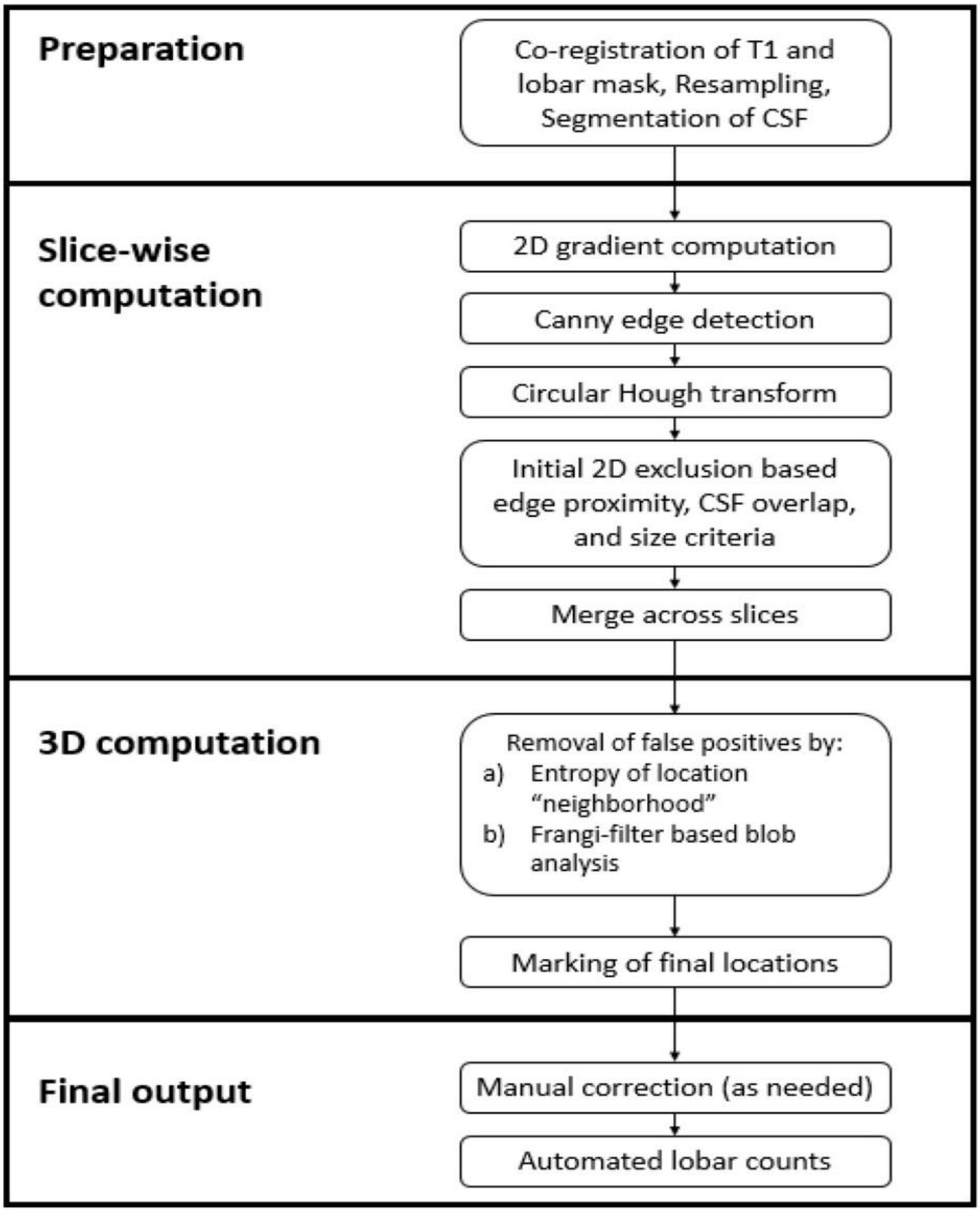


Fig 16 :mri preprocessing the entire algorithm pipeline is described by the flowchart

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Case study

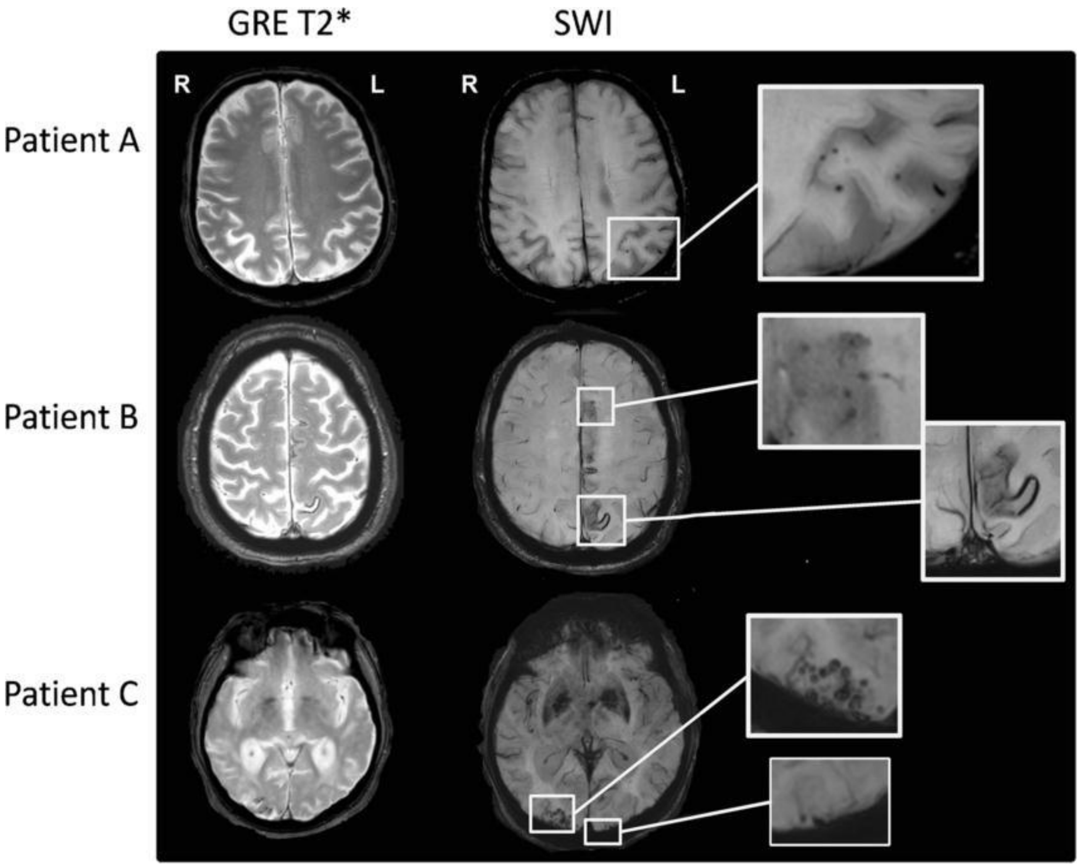


Fig 17:gre t2*–weighted and swi sequences for patients a, b,and c. In patient a, focal microbleeds corresponding to probable focal caa were not visualized in gre t2*–weighted mri. In patient b, more focal lesions were visualized with swi sequences. In patient c, probable focal caa was initially observed only in the right occipital cortex with gre t2*–weighted sequence, and a second zone of probable focal caa in the left occipital cortex was visualized with swi sequences. Gre t2*–weighted and swi sequences are in the same section thickness. R, right; l, left.

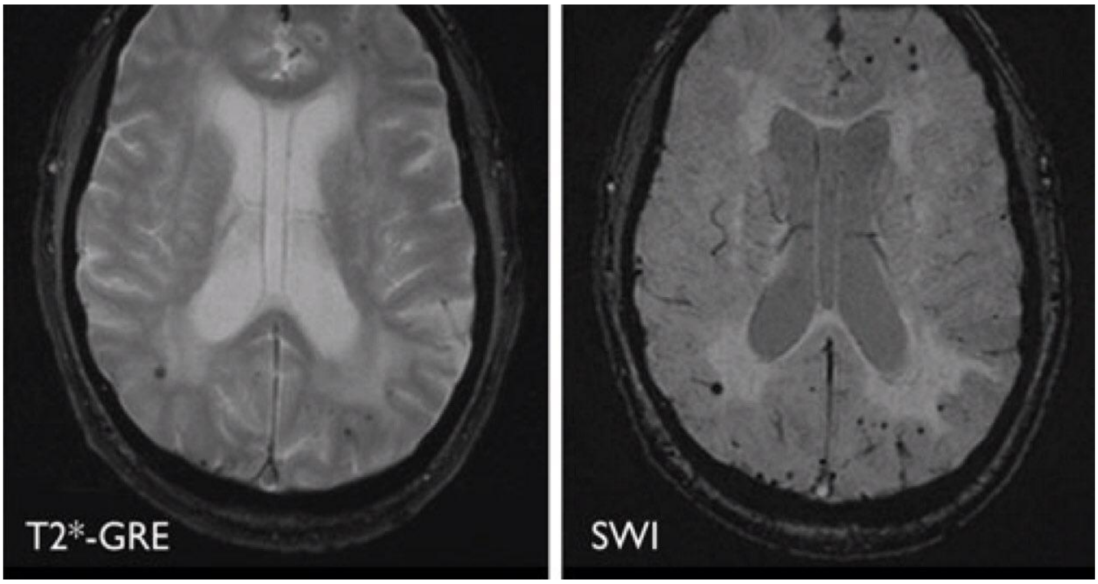


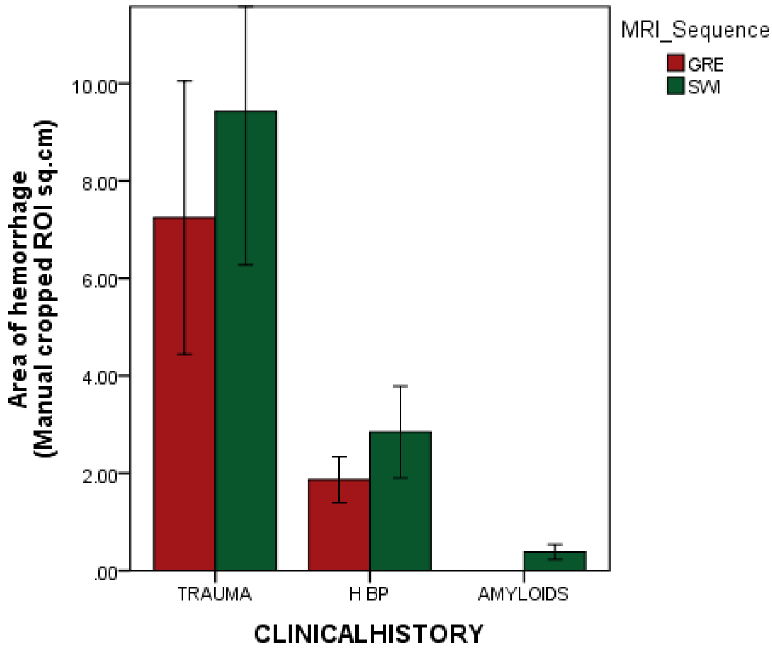
Fig:18 cerebral microbleeds (cmb) cmbs are defined as small, rounded, homogeneous, hypointense foci on t2*gre or swi mri sequences. Cmbs are mainly associated with two types of sporadic small vessel disease: hypertensive arteriopathy or cerebral amyloid angiopathy.

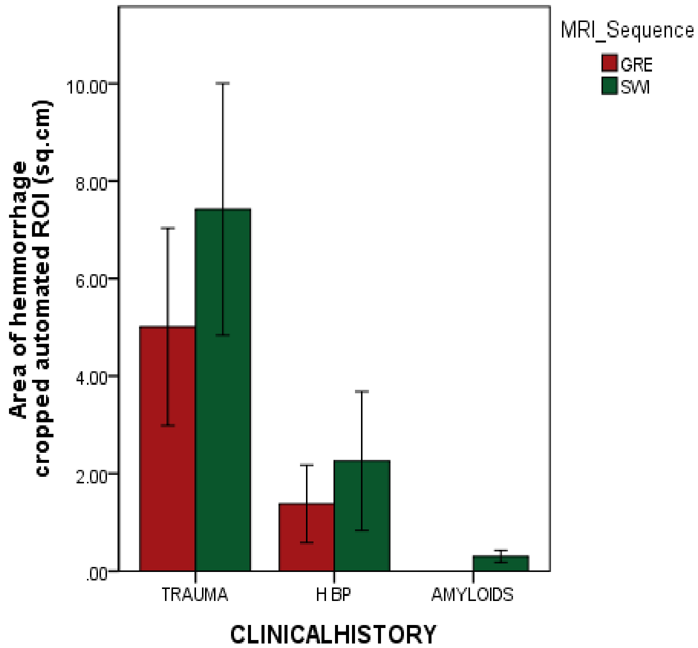
Current consensus MRI criteria for cerebral microbleed identification and their rationale

Criterion	Rationale
• Homogeneous hypointense lesions (black) on T2*-GRE MRI or SWI	To ensure the lesion is paramagnetic and likely to contain blood-breakdown products
• Well-defined rounded or ovoid in shape (rather than linear)	To exclude blood vessels and distinguish CMBs from cortical subarachnoid blood or superficial cortical siderosis (the latter may have separate relevance for diagnosing small vessel disease)
• 'Blooming' effect on T2*-GRE and SWI compared to T1- or T2-weighted sequences	Ensures that the lesion has susceptibility effect
• Small	The size should be used very conservatively in the identification of CMBs, and a precise upper limit is probably not critical
• Devoid of signal hyperintensity on T1-weighted or T2-weighted sequences	To avoid misclassifying some mimics, including cavernous malformations (bright on T2), metastatic melanoma (bright on T1)
• Surrounded by brain parenchyma (at least half of the lesion)	To include very superficial cortical lesions, which may be seen in cerebral amyloid angiopathy
• Clinical history excluding traumatic diffuse axonal injury	To avoid mixing secondary traumatic CMBs with CMBs caused by small vessel disease
• Differentiated from other hypointense lesions or artefacts ('microbleed mimics')	A reminder to consider these mimics

Sequence comparing-GRE vs SWI

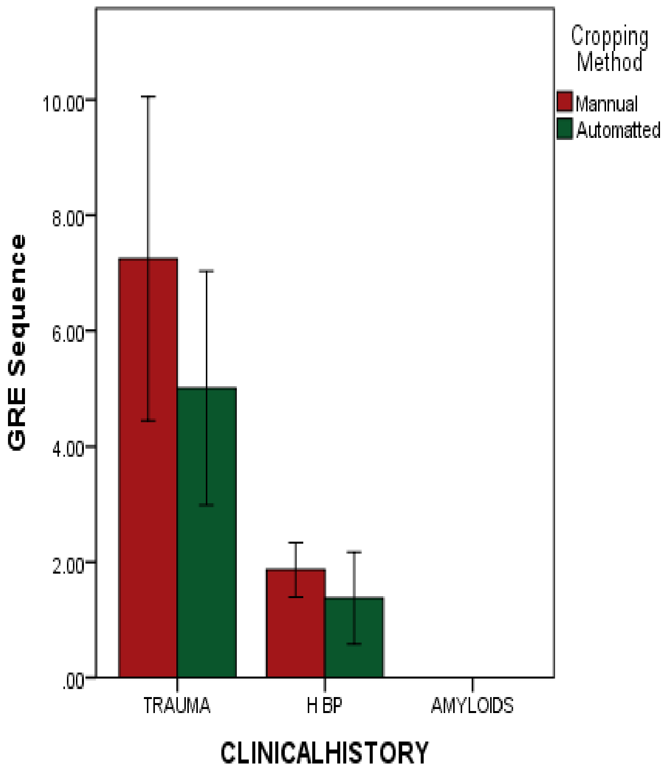
Graph .1. showing the comparison of gre vs swi

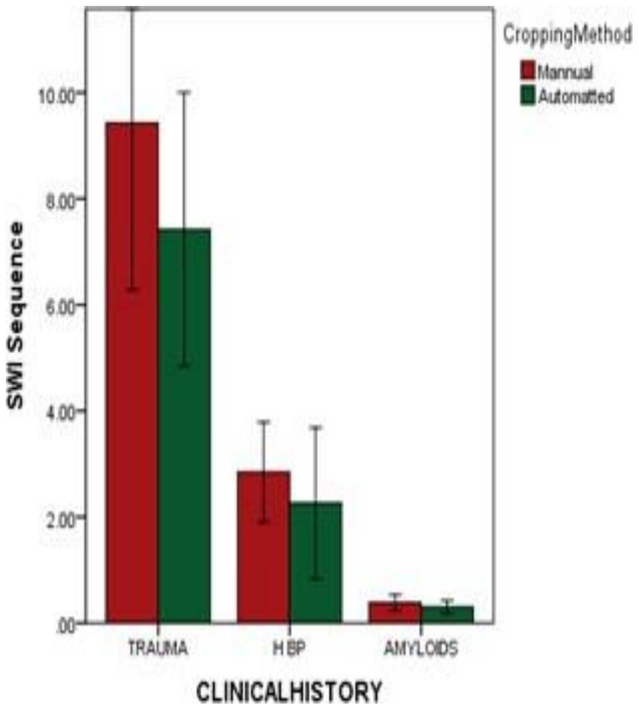




Comparing of cropping method- manual vs automatted

Graph.2 showing the comparison of GRE vs SWI





Discussion

Patients with brain hemorrhage were included and the qualitative assessment was done for the presence of blooming by radiologist. If present, areas are measured in quantitative manner by both manual and automatic methods with image software. Areas are measured manually in sq.cm from the same slices which shows greater hemorrhages in gre and swi sequence. Areas are measured automatically from the same slices which shows greater hemorrhages in gre and swi sequence using image software the areas of hemorrhage are cropped and converted into the binary image and the threshold and measured automatically and calibrated and the unit is given as sq.cm.

The values of manual and automated methods are further analyzed and grouped to derive mean and standard deviation based on the clinical observation such as trauma, high blood pressure and amyloidal hemorrhages.

Limitation of SWI

Apart from the advantages associate with swi, there are limitations some concerned with SWI, such as

- There is no gold standard view for hemorrhages to validate its reliability in MRI
- There will be little confusion in the detection of calcifications

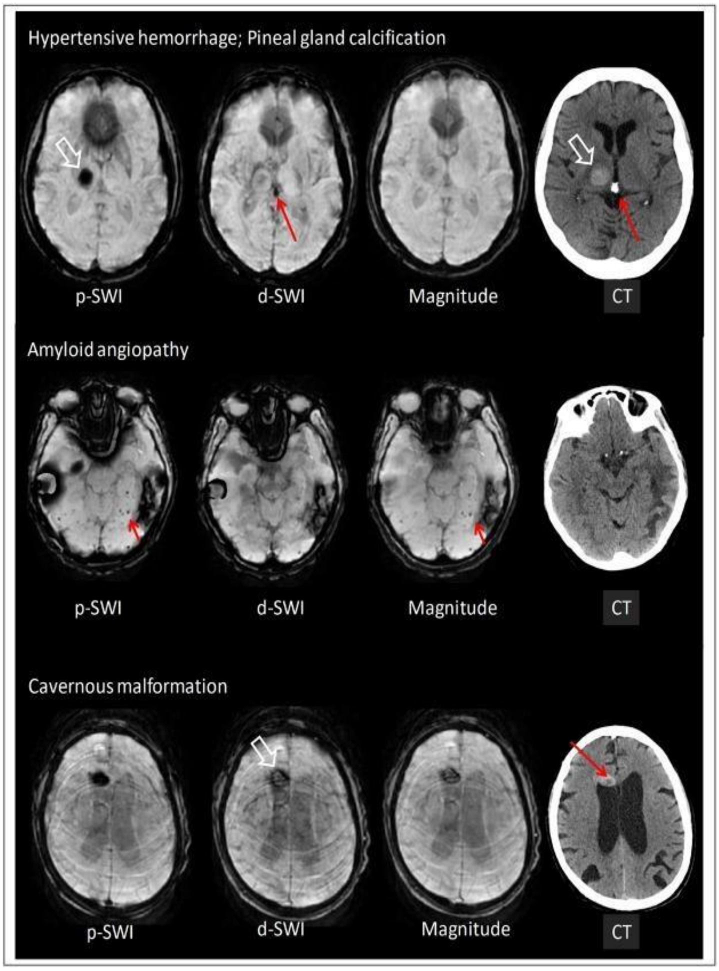


Fig 19: improved differentiation of calcification from hemosiderin using paramagnetic- and diamagnetic-specific magnetic resonance susceptibility weighted imaging (p-SWI, d-SWI).

- SWI represents an improvement over simple magnitude based t2*-weighted gre imaging, previously the main tool utilized for detection of iron containing structures, blood products, and calcifications. SWI remains a clinically relevant imaging technique, which has not yet been made obsolete by quantitative susceptibility mapping (qsm) 10., 13., 14., 15., 16., which remains primarily a research tool and has yet to achieve widespread clinically implementation.

Conclusion

In this prospective study, 25patients have been included with brain hemorrhage and have performed qualitative assessment for the presence of blooming. If present, areas are measured in quantitative manner by both manual and automatic methods.

In this study, we showed that SWI has higher sensitivity for micro hemorrhage detection when compared to GRE. Additionally, we found that the sensitivity and reliability of hemorrhage detection using automated area measurement methods is high when compared to manual area measurement methods.

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