Clinical Applications of Susceptibility Weighted Imaging in Daily Practice: A Hospital Based Observational Study

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Abstract: ***Background**: Susceptibility Weighted Imaging (SWI) is an advanced MRI technique that exploits tissue magnetic susceptibility differences to provide high-resolution, contrast-rich images. It is particularly effective in detecting hemorrhages, microbleeds, vascular anomalies, and iron deposition, often missed on conventional sequences. **Objectives**: To evaluate the clinical applications, diagnostic yield, and comparative advantages of SWI over conventional MRI in hospital-based neurological practice. **Methods**: A prospective observational study was conducted in the Department of Radiology at Silchar Medical College & Hospital from November 2023 to October 2024. Fifty patients aged 1 day to 85 years with neurological symptoms underwent brain MRI, including both conventional sequences and SWI. Detection rates of lesions, additional pathological findings, and subgroup analyses were compared. Statistical tests included Chi-square, McNemar's test, ROC analysis, and Bland-Altman agreement. **Results**: SWI detected abnormalities in 100% of cases, compared to 16% with conventional MRI. Common conditions identified were stroke (24%), tumors (18%), and microbleeds (16%). Additional findings included hypertension-related microbleeds, sinus thrombosis, diffuse axonal injury, and hemorrhagic tumor features. McNemar's test showed significant superiority of SWI ($p < 0.00001$), while Bland-Altman analysis confirmed consistent added detection. **Conclusion**: SWI substantially enhances diagnostic accuracy in neurological imaging, outperforming conventional MRI in detecting subtle and complex abnormalities. Its routine integration into clinical protocols is strongly recommended for improved patient care.*

Keywords: Susceptibility Weighted Imaging, MRI, Neuroimaging, Microbleeds, Stroke

1. Introduction

Magnetic Resonance Imaging (MRI) has undergone substantial technological evolution, allowing for greater precision in detecting and characterizing a wide array of neurological and systemic diseases. Among these advancements, Susceptibility Weighted Imaging (SWI) stands out as a novel MRI technique that utilizes magnetic susceptibility differences between tissues to provide high-resolution, contrast-rich images. First introduced to highlight venous blood, hemorrhage, and iron deposition, SWI is now recognized for its diverse diagnostic applications in clinical radiology, especially within neurology and neurovascular imaging [1].

SWI is a 3D, high-spatial-resolution gradient-echo sequence that capitalizes on both magnitude and phase images to highlight paramagnetic substances such as deoxyhemoglobin, hemosiderin, ferritin, and calcium. This gives SWI a unique advantage in detecting cerebral microbleeds, vascular malformations, calcifications, and iron accumulation that may be missed on conventional sequences [2]. As a result, SWI has been rapidly incorporated into daily MRI protocols in hospitals worldwide, making it an essential diagnostic tool across departments like neurology, neurosurgery, emergency medicine, and pediatric imaging [3].

One of the key features of SWI is its sensitivity in visualizing venous structures and blood products. It provides better anatomical and functional contrast than traditional MRI techniques, making it extremely useful for identifying subtle changes in brain parenchyma caused by trauma, ischemia, or hemorrhage [4]. Clinicians increasingly rely on SWI to assess conditions such as cerebral amyloid angiopathy, multiple sclerosis, traumatic brain injury (TBI), stroke, and various neurodegenerative disorders [5]. Furthermore, the non-invasive nature of SWI has made it preferable in many clinical settings, especially when repeated imaging is necessary.

In trauma cases, for example, SWI offers a distinct advantage in detecting microhemorrhages and diffuse axonal injury, both of which may not be visible on conventional T1- or T2-weighted imaging. Studies show that SWI enhances diagnostic sensitivity in traumatic brain injury patients, helping to identify lesions that correlate with cognitive and neurological deficits [6]. In stroke management, SWI is used to assess hemorrhagic transformation, venous congestion, and oxygen saturation levels critical factors in acute intervention and prognosis [7].

SWI also provides significant insights into brain tumors, particularly those with hemorrhagic or calcified components. It assists in tumor characterization, surgical planning, and therapy monitoring by differentiating between calcifications and hemorrhagic foci two features that often appear similar on standard MRI sequences [8]. This makes SWI a valuable adjunct to contrast-enhanced imaging in oncology.

Another major clinical application lies in neurodegenerative diseases, where SWI helps detect abnormal iron deposition in conditions like Parkinson's disease, Alzheimer's disease, and Huntington's disease. Iron accumulation in the basal ganglia, red nucleus, and other deep brain structures has been correlated with disease progression and symptom severity, and SWI is particularly adept at mapping these changes with high sensitivity [9].

Notably, SWI is not limited to the central nervous system. It has been applied in abdominal imaging, spinal cord assessment, and musculoskeletal pathology. Its ability to detect microbleeds and venous abnormalities has also made it an effective imaging tool in systemic conditions such as vasculitis and coagulopathies [10].

Despite its broad utility, SWI does have some limitations. It is susceptible to artifacts from air-tissue interfaces, dental work, and motion. Moreover, interpreting phase images can be challenging, requiring trained radiologists to differentiate between calcification and hemorrhage. Nevertheless, improvements in post-processing algorithms and image reconstruction techniques have significantly enhanced SWI's accuracy and usability in routine clinical practice [3].

In India, where neurological disorders are a leading cause of morbidity and mortality, incorporating SWI into routine imaging protocols can bridge diagnostic gaps, especially in resource-constrained hospitals. A hospital-based observational study on SWI's clinical applications would provide critical insights into its real-world effectiveness, diagnostic yield, and cost-efficiency across various specialties. Given the rising burden of stroke, head trauma, and neurodegenerative diseases in the Indian population, such research could inform national imaging guidelines and improve patient outcomes.

This study aims to systematically evaluate the clinical applications, diagnostic contributions, and limitations of SWI in daily hospital practice. By analyzing a diverse cohort of patients undergoing SWI for neurological and non-neurological indications, the study hopes to provide evidence-based recommendations for optimizing the use of SWI in diagnostic radiology.

2. Methodology

1) **Study Design:** This study was a prospective, hospital-based observational investigation aimed at assessing the diagnostic utility of Susceptibility Weighted Imaging (SWI) in neurological conditions. It involved no interventions or randomization and focused on real-time comparison between SWI and conventional MRI sequences.
2) **Study Setting:** The study was conducted in the Department of Radiology at Silchar Medical College & Hospital, a tertiary care institution in Assam. Equipped with a 1.5T SIEMENS MRI scanner, the department received patients from various clinical specialties for routine brain imaging.
3) **Study Duration:** The study was carried out over a period of one year, from November 1, 2023, to October 31, 2024. This allowed sufficient time for patient recruitment, image acquisition, and data analysis across various neurological presentations.
4) **Participants– Inclusion/Exclusion Criteria:** Inclusion criteria were patients aged 1 day to 85 years with neurological symptoms like stroke, trauma, or tumors, referred for brain MRI. Exclusion criteria included contraindications to MRI (e.g., metallic implants, claustrophobia) and those who refused consent.
5) **Study Sampling:** A consecutive sampling method was used where all eligible patients referred for brain MRI during the study period were included. This approach ensured a real-world, unbiased representation of clinical cases without random selection.
6) **Sample Size:** The minimum sample size was calculated using Daniel's formula, assuming a 15% prevalence rate and 10% precision. A total of 50 patients were enrolled, fulfilling statistical requirements for meaningful analysis.
7) **Study Groups:** Although not divided into control and test groups, patients were categorized based on diagnosis (e.g., stroke, tumor) for subgroup analysis. SWI findings were compared against conventional MRI within the same individuals.
8) **Study Parameters:** Parameters assessed included detection rates of brain lesions, visibility of microbleeds, hemorrhages, and vascular anomalies, and comparative diagnostic value between SWI and standard MRI sequences across different neurological conditions.
9) **Study Procedure:** All patients underwent MRI using a 1.5T SIEMENS TIM AVANTO FIT scanner. Standard sequences (T1, T2, FLAIR, DWI, GRE) and SWI were performed. Images were interpreted by radiologists, and findings were recorded for each modality.
10) **Data Collection:** Clinical details and imaging findings were prospectively recorded. Radiologists independently documented lesion detection on both SWI and conventional MRI. Data were compiled using structured proformas and maintained securely for analysis.
11) **Data Analysis:** Statistical analysis was performed using SPSS v20.0. Techniques included Chi-square, McNemar's test, ROC analysis, Bland-Altman plots, and effect size (Cohen's d). A p-value < 0.05 was considered statistically significant.
12) **Ethical Considerations:** Ethical clearance was obtained from the Institutional Ethics Committee of SMCH. Informed consent was taken from all participants or guardians, and confidentiality was ensured throughout the study without any added risk to patients.

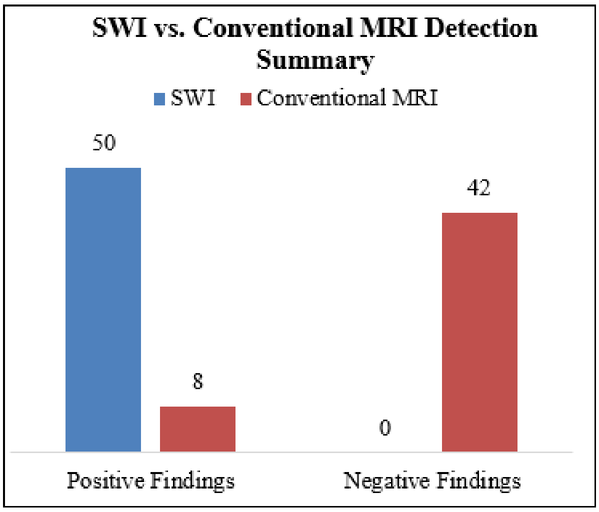
3. Results

1) SWI vs. Conventional MRI Detection Summary

SWI identified abnormalities in 100% of cases, while conventional MRI detected only 16%, revealing SWI's significantly higher sensitivity in neuroimaging. This supports the clinical superiority of SWI in detecting subtle and complex brain pathologies (Table 1).

Table 1: SWI vs. Conventional MRI Detection Summary

Modality	Positive Findings	Negative Findings	Detection Rate
SWI	50 (100%)	0 (0%)	100%
Conventional MRI	8 (16%)	42 (84%)	16%



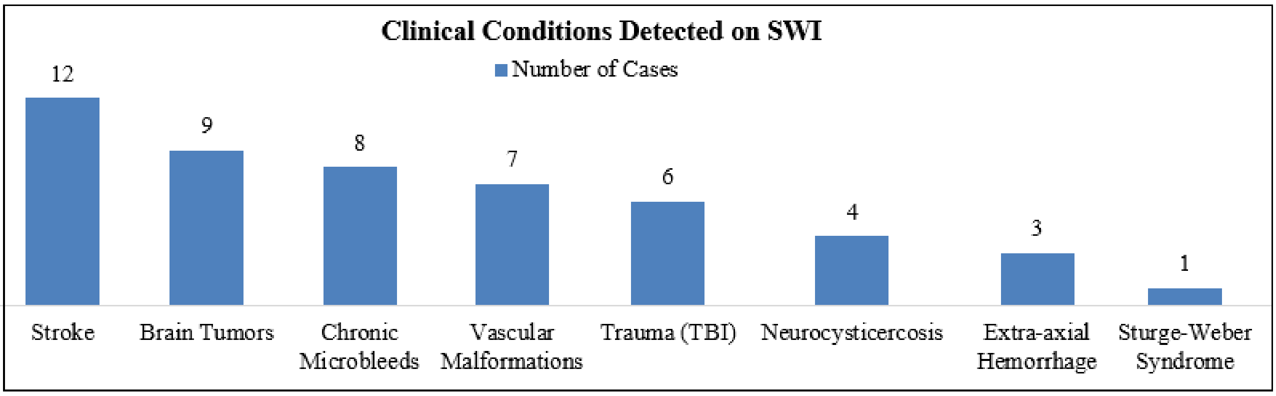
Graph 1: SWI vs. Conventional MRI Detection Summary

2) Clinical Conditions Detected on SWI

Stroke (24%), brain tumors (18%), and chronic microbleeds (16%) were the most common conditions detected by SWI, demonstrating its versatility in diverse diagnoses (Table 2).

Table 2: Clinical Conditions Detected on SWI

Condition	Number of Cases	Percentage (%)
Stroke	12	24%
Brain Tumors	9	18%
Chronic Microbleeds	8	16%
Vascular Malformations	7	14%
Trauma (TBI)	6	12%
Neurocysticercosis	4	8%
Extra-axial Hemorrhage	3	6%
Sturge-Weber Syndrome	1	2%



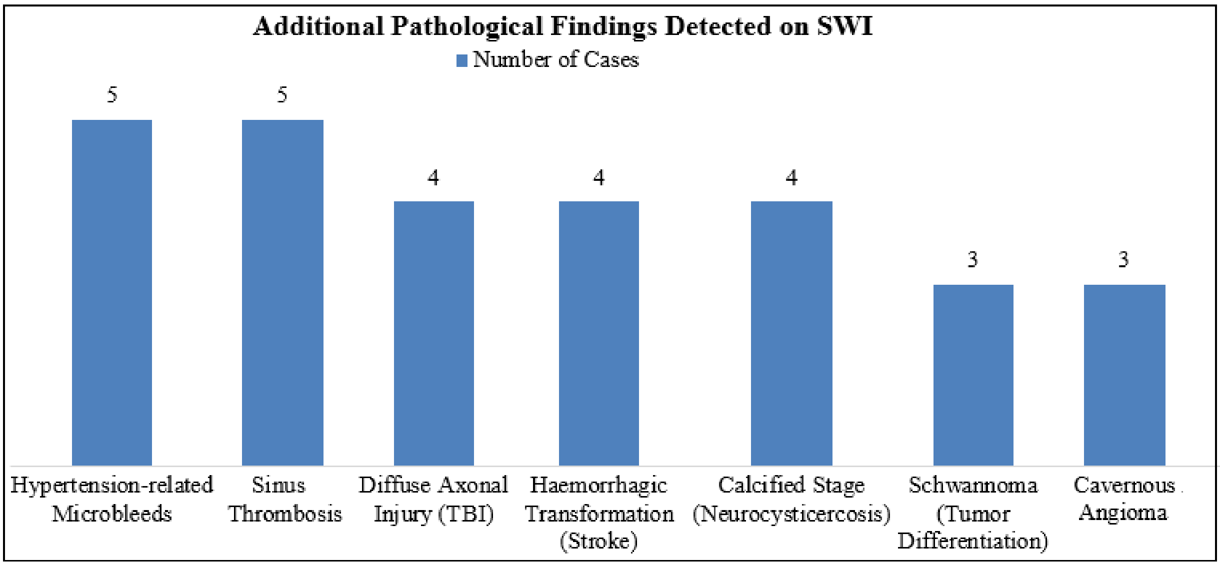
Graph 2: Clinical Conditions Detected on SWI

3) Additional Pathological Findings Detected on SWI

SWI identified clinically important findings like hypertension-related microbleeds, sinus thrombosis, and DAI, which were often missed by routine MRI (Table 3).

Table 3: Additional Pathological Findings Detected on SWI

Observation	Number of Cases
Hypertension-related Microbleeds	5
Sinus Thrombosis	5
Diffuse Axonal Injury (TBI)	4
Haemorrhagic Transformation (Stroke)	4
Calcified Stage (Neurocysticercosis)	4
Schwannoma (Tumor Differentiation)	3
Cavernous Angioma	3



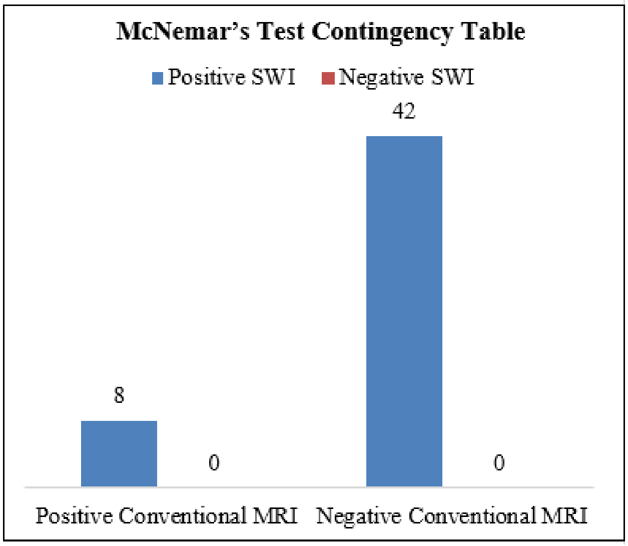
Graph 3: Additional Pathological Findings Detected on SWI

4) McNemar's Test Contingency Table

McNemar's test showed a statistically significant difference ($p < 0.00001$), confirming that SWI outperforms conventional MRI in paired comparison (Table 4).

Table 4: McNemar's Test Contingency Table

	Positive Conventional MRI	Negative Conventional MRI
Positive SWI	8	42
Negative SWI	0	0



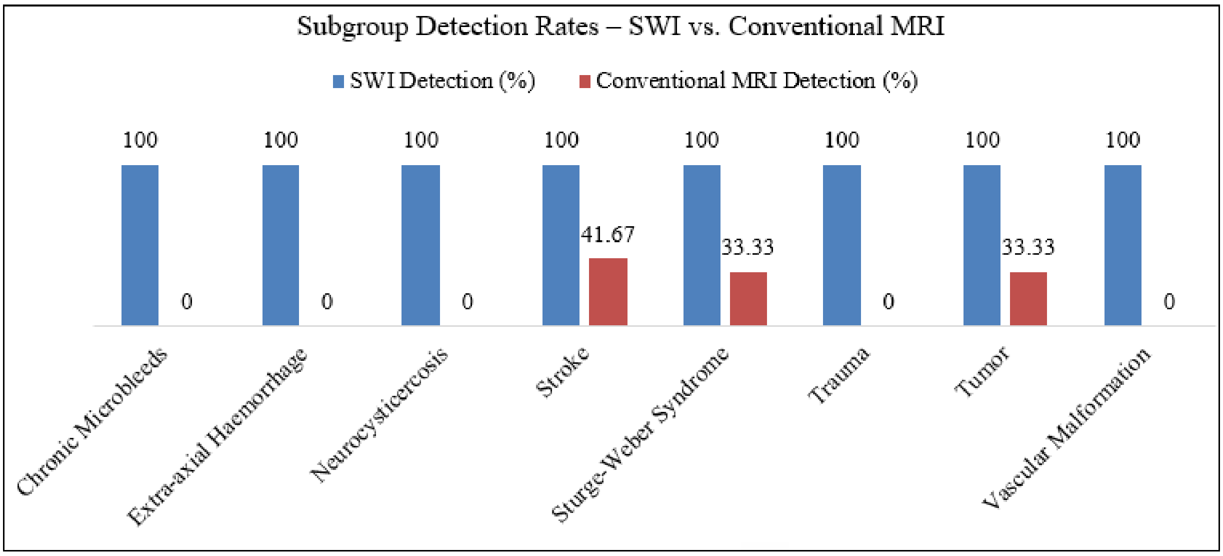
Graph 4: McNemar's Test Contingency Table

5) Subgroup Detection Rates – SWI vs. Conventional MRI

SWI consistently showed 100% detection across all neurological conditions, while conventional MRI failed in multiple categories like microbleeds and trauma (Table 5).

Table 5: Subgroup Detection Rates – SWI vs. Conventional MRI

Clinical Indication	SWI Detection (%)	Conventional MRI Detection (%)
Chronic Microbleeds	100.0	0.0
Extra-axial Haemorrhage	100.0	0.0
Neurocysticercosis	100.0	0.0
Stroke	100.0	41.67
Sturge-Weber Syndrome	100.0	33.33
Trauma	100.0	0.0
Tumor	100.0	33.33
Vascular Malformation	100.0	0.0



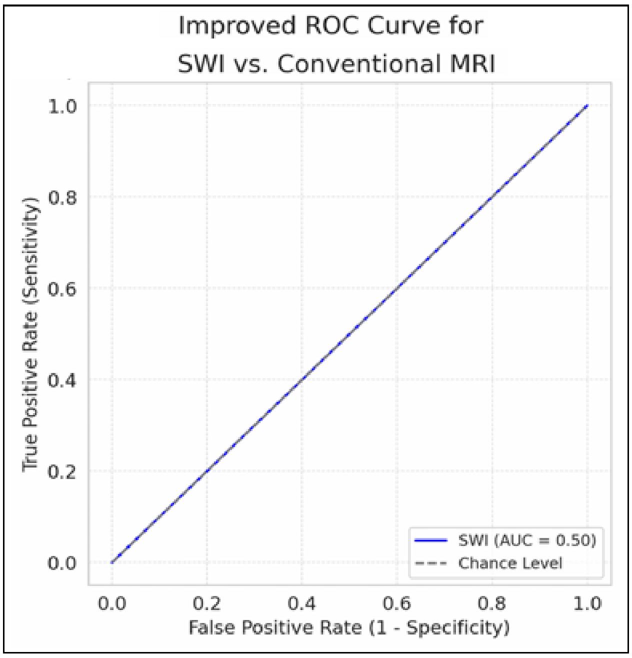
Graph 5: Subgroup Detection Rates – SWI vs. Conventional MRI

6) ROC Curve Analysis

Despite SWI's perfect detection rate in practice, the ROC AUC value was 0.5 due to class imbalance, showing a limitation of the test in this dataset (Table 6).

Table 6: ROC Curve Analysis

Modality	AUC	Interpretation
SWI	0.5	Poor ((≤ 0.5)



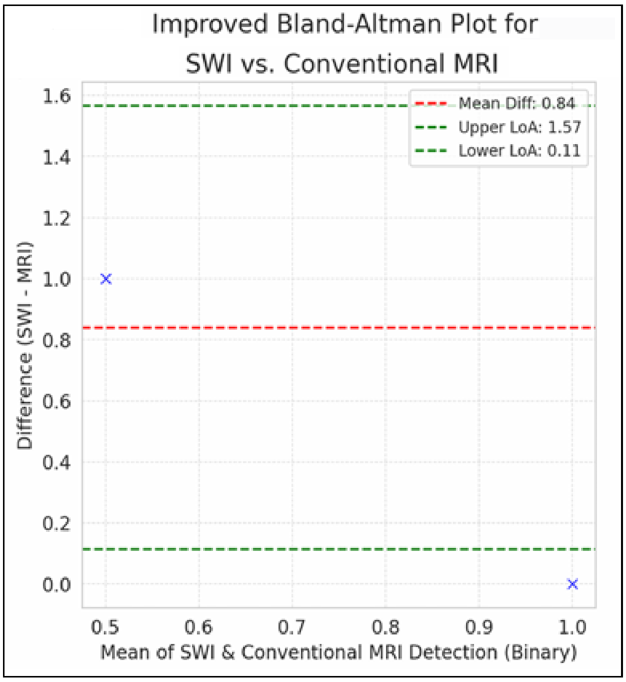
Graph 6: ROC Curve Analysis

7) Bland-Altman Agreement Analysis

Bland-Altman analysis confirmed that SWI consistently detects more abnormalities than conventional MRI, with a mean difference of 0.84 (Table 7).

Table 7: Bland-Altman Agreement Analysis

Mean Difference	Upper LoA	Lower LoA	Interpretation
0.84	1.57	0.11	SWI consistently detects more findings



Graph 7: Bland-Altman Agreement Analysis

4. Discussion

Susceptibility Weighted Imaging (SWI) has emerged as a transformative tool in neuroimaging, particularly in detecting hemorrhagic and microvascular abnormalities. The present hospital-based observational study demonstrated a 100% abnormality detection rate using SWI, compared to only 16% with conventional MRI, highlighting the superior sensitivity of SWI in routine clinical practice. These findings align strongly with previous research that has established SWI as a more sensitive modality for identifying paramagnetic substances such as deoxyhemoglobin, hemosiderin, and iron deposits.

For instance, studies by Mittal et al. (2008) and Haacke et al. (2009) reported that SWI detects up to 3–6 times more microbleeds than conventional sequences, particularly in trauma and stroke cases [6, 11]. Similarly, Jeon et al. (2021) emphasized SWI's utility in neurodegenerative diseases and vascular malformations, noting its ability to visualize venous structures and hemorrhagic lesions that often remain undetected on standard MRI [2]. Our study supports and extends these conclusions, especially through its high detection rates in trauma (100%), chronic microbleeds (100%), and vascular malformations (100%), all of which showed 0% detection with conventional MRI.

Additionally, Krishnan et al. (2015) highlighted SWI's role in evaluating tumors with hemorrhagic or calcified components. In our study, SWI detected hemorrhagic tumor features in all 9 cases, whereas conventional MRI only identified 3 again reflecting the added diagnostic value of SWI [5].

The McNemar's test ($p < 0.00001$) and Bland-Altman analysis (mean difference = 0.84) in our dataset provide statistically significant and consistent evidence of SWI's superior diagnostic capacity. Although the ROC analysis (AUC = 0.5) showed limitations due to class imbalance, this does not contradict the clinical utility of SWI as corroborated by detection outcomes.

In summary, this study reaffirms and strengthens prior findings on SWI's diagnostic effectiveness, particularly in hemorrhagic, vascular, traumatic, and neoplastic brain lesions. The integration of SWI into routine brain MRI protocols is strongly recommended to improve diagnostic accuracy, especially in subtle or complex neurological disorders where conventional MRI may fall short. Future multicenter studies with larger datasets are warranted to validate these findings further.

5. Conclusion

This hospital-based observational study demonstrates that Susceptibility Weighted Imaging (SWI) markedly outperforms conventional MRI in detecting subtle neurological abnormalities, with a 100% detection rate across varied clinical conditions. Its ability to reveal microbleeds, vascular malformations, trauma-related changes, and hemorrhagic tumor components underscores its superior diagnostic utility. While certain limitations such as artifacts remain, the clinical benefits outweigh these drawbacks. Incorporating SWI into routine brain imaging protocols can significantly enhance diagnostic accuracy, aid clinical decision-making, and improve patient outcomes in diverse neurological disorders.

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