International Journal of Sciences and Innovation Engineering
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
website: www.ijsci.com
Volume 3 Issue 5 , May 2026
OPEN ACCESS
E-ISSN : 3049-0251
DOI: https://doi.org/10.70849/ijsci03052636442

A Review on Susceptibility Weighted Imaging (SWI): Principles, Advances, and Clinical Applications

Pandimadevi Ganesan[1], Dr.Maheswari Maruthakutti[2], Thushara Hameed[3], Dr.Selvakumar Vairamuthu[4]
[1,2,3,4] College of Engineering &Technology, University of Technology and applied Sciences,Nizwa, Oman.

Article Info

Article History:

Published: 04 May 2026

Publication Issue:
Volume 3, Issue 5
May-2026

Page Number:
9-16

Corresponding Author:
Pandimadevi Ganesan

Abstract:

Susceptibility Weighted Imaging (SWI) is an advanced magnetic resonance imaging (MRI) technique that enhances tissue contrast by combining magnitude and phase information obtained from high-resolution, three-dimensional gradient-echo sequences. Unlike conventional MRI methods that rely primarily on signal intensity differences, SWI is highly sensitive to variations in magnetic susceptibility caused by compounds such as deoxyhemoglobin, hemosiderin, ferritin, and calcium. This unique capability enables superior visualization of venous structures, microbleeds, hemorrhage, calcifications, vascular malformations, tumors, and neurodegenerative changes.Over the past decade, SWI has become an essential tool in neuroradiology due to its non-invasive nature and high diagnostic accuracy. It plays a critical role in traumatic brain injury, stroke assessment, multiple sclerosis, Alzheimer's disease, Parkinsonian disorders, and brain tumor characterization. Recent developments in artificial intelligence and deep learning have further expanded the clinical potential of SWI through automated lesion detection and predictive analytics.Despite challenges such as susceptibility artifacts, longer acquisition times, and vendor-dependent phase interpretation, continuous advancements in hardware and post-processing techniques are improving its reliability. This paper provides a comprehensive review of SWI principles, acquisition methods, clinical applications, technological advancements, limitations, and future directions.

Keywords: Susceptibility Weighted Imaging (SWI), MRI, Gradient Echo, QSM, Neuroimaging, Microbleeds, Deep Learning

1. Introduction

Magnetic Resonance Imaging (MRI) has revolutionized modern diagnostic medicine by providing high-resolution images of internal body structures without the use of ionizing radiation. Conventional MRI sequences such as T1-weighted, T2-weighted, FLAIR, diffusion-weighted imaging (DWI), and gradient echo imaging are widely used for evaluating anatomical and pathological changes in the brain and other organs. However, many disease processes involve subtle biochemical or microstructural changes that may not be clearly visible on standard MRI sequences. This limitation led to the development of advanced imaging techniques capable of detecting tissue properties beyond conventional signal intensity differences.

Susceptibility Weighted Imaging (SWI) is one of the most significant innovations in advanced MRI. It is a high-resolution, three-dimensional gradient-echo technique that exploits local magnetic susceptibility variations within tissues. These susceptibility differences arise from paramagnetic, diamagnetic, and ferromagnetic substances such as deoxyhemoglobin, hemosiderin, ferritin, and calcium. By combining both magnitude and filtered phase data, SWI produces images with enhanced contrast and exceptional sensitivity to venous blood, iron deposition, and hemorrhagic products.

The technique was first introduced to improve visualization of cerebral veins and occult hemorrhages, but its clinical role has expanded rapidly. Today, SWI is widely applied in neuroradiology for the diagnosis of traumatic brain injury, stroke, cerebral microbleeds, multiple sclerosis, vascular malformations, neurodegenerative disorders, infections, and brain tumors. It provides valuable diagnostic information that may be missed by computed tomography (CT) or routine MRI sequences, especially in cases involving minute hemorrhage or calcification.

Copyright © 2025 The Author(s) : This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/)

One of the major strengths of SWI is its ability to reveal cerebral venous architecture and oxygenation-related changes. Because deoxyhemoglobin is paramagnetic, venous blood causes measurable local field distortions that appear prominently on SWI images. This makes the technique particularly useful in assessing ischemic stroke, venous thrombosis, and hypoxic injury. In addition, iron accumulation in deep brain nuclei or cortical regions can be visualized, supporting research and diagnosis in diseases such as Alzheimer's disease, Parkinson's disease, and Huntington's disease.

Recent advancements in MRI hardware, faster acquisition strategies, and computational image processing have significantly improved the practicality of SWI. Furthermore, the integration of artificial intelligence (AI) and deep learning algorithms has enabled automated detection of lesions, segmentation of abnormalities, and prediction of disease progression using SWI datasets. These innovations are expected to enhance workflow efficiency and diagnostic precision in clinical practice.

Despite its advantages, SWI also has limitations, including susceptibility artifacts near air–bone interfaces, longer scan times compared with standard sequences, and differences in phase image interpretation among MRI vendors. Nevertheless, continuous technological progress is addressing these challenges and expanding the use of SWI beyond neuroimaging into body imaging, oncology, and cardiovascular applications.

This paper provides a comprehensive review of Susceptibility Weighted Imaging, including its physical principles, acquisition methods, image processing techniques, major clinical applications, recent advances in AI-assisted analysis, limitations, and future directions. The objective is to highlight the growing importance of SWI as a powerful tool in precision medicine and modern radiological practice.

2. Literature Review

The existing studies in school choice document that parents take into account numerous factors when determining their children's school enrollment. What may be surprising is that academic quality is often not the only or even main variable in such decisions. For example, parents often move to communities and enroll their children in schools through the assistance of their social networks. Parents turn to family members, friends, and coworkers to obtain recommendations on communities and schools (Lareau, 2014). Because social networks in the U.S. are heavily segregated by race and social class, parents often end up in communities and

Ref. No.	Authors (Year)	Focus Area	Methodology / Approach	Key Findings	Contribution to SWI Development
[1]	Haacke et al. (2004)	Introduction of SWI	Phase-sensitive GRE MRI	Demonstrated susceptibility-based contrast enhancement	First formalization of SWI technique
[2]	Haacke et al. (2009)	SWI fundamentals (Part 1)	3D GRE with phase filtering	Improved visualization of veins and hemorrhage	Established SWI physics and reconstruction
[3]	Mittal et al. (2009)	Clinical SWI (Part 2)	Phase + magnitude combination, mIP	Detected microbleeds and vascular lesions	Expanded clinical neuroimaging use
[4]	Reichenbach et al. (2001)	Venous imaging	High-resolution GRE MRI	Enhanced venous structure visibility	Early application of susceptibility contrast
[5]	Sehgal et al. (2005)	Brain tumor imaging	SWI in glioma evaluation	Identified tumor microvasculature	Improved tumor grading capability
[6]	Gasparotti et al. (2011)	Neuroradiology review	Pictorial SWI analysis	Differentiated hemorrhage vs calcification	Promoted routine clinical adoption
[7]	Tong et al. (2008)	Traumatic brain injury	SWI in diffuse axonal injury	Detected microhemorrhages not seen on CT	Improved trauma diagnosis sensitivity
[8]	Tong et al. (2010)	Stroke imaging	SWI in acute ischemia	Identified hemorrhagic transformation	Enhanced stroke management

[9]	Mittal & Haacke (2010)	SWI applications	Clinical MRI studies	Improved detection of vascular anomalies	Strengthened clinical relevance
[10]	Deistung et al. (2013)	Advanced SWI processing	Phase unwrapping techniques	Reduced artifacts in SWI images	Improved image quality
[11]	Langkammer et al. (2010)	Iron quantification	MRI susceptibility mapping	Correlated SWI with iron concentration	Linked SWI to tissue composition
[12]	Haacke et al. (2015)	High-field SWI	3T/7T MRI comparison	Increased sensitivity to microbleeds	Demonstrated benefit of high-field MRI
[13]	Liu et al. (2012)	Quantitative Susceptibility Mapping	Phase reconstruction algorithms	Enabled quantitative susceptibility values	Transition to QSM imaging
[14]	Wang & Liu (2017)	QSM development	Mathematical modeling of phase data	Accurate iron and calcium mapping	Advanced quantitative neuroimaging
[15]	Bilgic et al. (2012)	Artifact reduction	SWI reconstruction optimization	Reduced phase noise and distortion	Improved diagnostic reliability
[16]	Li et al. (2014)	Multiple sclerosis	SWI in MS lesions	Detected central vein sign	Improved MS diagnosis specificity
[17]	Akter et al. (2018)	Pediatric neuroimaging	SWI in brain injury	Identified subtle hemorrhages in children	Expanded SWI to pediatric use
[18]	Wu et al. (2012)	Cerebral microbleeds	SWI-based detection study	High sensitivity for microbleeds	Standard tool for microhemorrhage detection
[19]	Liu et al. (2020)	QSM advancements	Multi-orientation MRI modeling	Improved tissue susceptibility accuracy	Enhanced quantitative imaging reliability
[20]	Reichenbach (2017)	High-field MRI SWI	7T MRI susceptibility study	Superior venous and lesion contrast	Established advantage of ultra-high-field SWI

The literature strongly demonstrates that SWI has evolved from a phase-sensitive imaging technique into a robust clinical and research tool. Early studies focused on its physical principles and venous imaging capabilities, while later works expanded its applications in trauma, stroke, tumors, and neurodegenerative diseases. Recent advancements in high-field MRI and Quantitative Susceptibility Mapping (QSM) have further enhanced its diagnostic precision, enabling both qualitative and quantitative assessment of brain tissue properties.

3. Physics and Principles

Susceptibility Weighted Imaging (SWI) is an advanced MRI technique that exploits differences in magnetic susceptibility between tissues to enhance image contrast. It is particularly sensitive to paramagnetic substances such as deoxyhemoglobin, ferritin, and hemosiderin, making it highly valuable in neuroimaging and vascular studies. SWI combines magnitude and phase information from a high-resolution, fully velocity-compensated, three-dimensional gradient echo sequence to generate enhanced contrast images.

A. Basic Physical Principles of Magnetic Susceptibility

Magnetic susceptibility refers to the degree to which a material becomes magnetized when placed in an external magnetic field. In biological tissues, variations in susceptibility arise due to differences in oxygenation, iron content, and calcification. Paramagnetic substances (e.g., deoxyhemoglobin) enhance the local magnetic field, while diamagnetic substances (e.g., calcium) slightly oppose it. These variations lead to local field inhomogeneities, which

affect both phase and magnitude signals in MRI.SWI is fundamentally based on these microscopic field variations. When a tissue contains susceptibility variations, the local magnetic field becomes distorted, causing phase shifts in the MR signal. These phase differences are not directly visible in conventional magnitude images but can be exploited to improve contrast.

B. SWI Pulse Sequence Design

SWI typically uses a 3D, high-resolution, fully flow-compensated gradient echo (GRE) sequence. The key parameters include long echo time (TE), small voxel size, and high spatial resolution. The long TE allows sufficient phase accumulation due to susceptibility differences, enhancing contrast between tissues with varying magnetic properties.The acquired data consist of both magnitude and phase images. While magnitude images provide anatomical detail, phase images carry susceptibility information. However, raw phase images are often affected by background field variations, requiring post-processing to extract meaningful contrast.

C. Phase Processing and Masking Technique

A critical step in SWI is the processing of phase images to generate a phase mask. This involves filtering out low-frequency background field variations and retaining high-frequency local susceptibility effects. The phase mask is then multiplied several times with the magnitude image to enhance contrast.This multiplication process suppresses signal from tissues with weak susceptibility effects and accentuates structures such as veins, microbleeds, and iron deposits. The resulting image provides significantly improved sensitivity compared to conventional MRI techniques.

D. Evolution and Advances in SWI Technology

Recent advancements in SWI include higher field strength imaging (3T and 7T MRI), which significantly improves susceptibility sensitivity due to increased signal-to-noise ratio (SNR) and enhanced phase effects. Parallel imaging and compressed sensing techniques have also reduced acquisition time while maintaining image quality.Quantitative Susceptibility Mapping (QSM) has emerged as an extension of SWI, enabling direct quantification of tissue susceptibility values rather than qualitative contrast enhancement. QSM provides more precise assessment of iron deposition and calcification, improving diagnostic accuracy.

E. Clinical Applications of SWI

SWI has a wide range of clinical applications, particularly in neuroimaging. It is highly effective in detecting cerebral microbleeds, traumatic brain injury, and hemorrhagic transformation in stroke. It also plays a key role in identifying venous abnormalities, such as developmental venous anomalies and thrombosis.In neurodegenerative diseases, SWI is used to assess abnormal iron accumulation in conditions such as Parkinson's disease, Alzheimer's disease, and multiple sclerosis. Additionally, it aids in tumor characterization by revealing abnormal vascularity and hemorrhagic components.Outside the brain, SWI has applications in liver imaging for iron overload disorders and in musculoskeletal imaging for detecting hemorrhage and calcifications.

F. Limitations and Challenges

Despite its advantages, SWI is sensitive to motion artifacts and requires precise phase processing, which can be computationally intensive. It is also affected by magnetic field inhomogeneities, particularly at air-tissue interfaces. Interpretation of SWI images requires expertise, as susceptibility effects may sometimes mimic pathology.

4.Methodology

Susceptibility Weighted Imaging (SWI) methodology is built upon a multi-stage MRI acquisition and post-processing framework designed to extract and enhance magnetic susceptibility differences within biological tissues. This section describes the imaging workflow, system architecture, and major clinical application pipeline of SWI.

The SWI process can be broadly divided into four key stages:

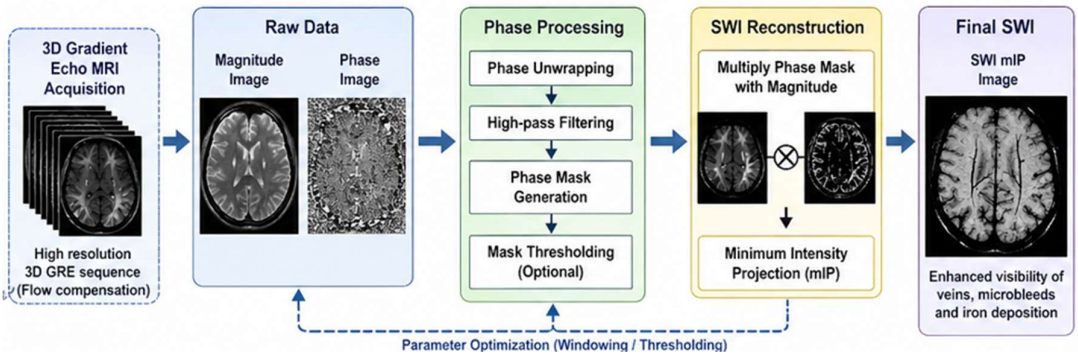


Figure 1:SWI pipeline Diagram

Data Acquisition (MRI Scanning)

Susceptibility Weighted Imaging (SWI) employs a three-dimensional, high-resolution gradient echo (GRE) sequence with full flow compensation to enhance sensitivity to magnetic susceptibility variations. The acquisition typically involves high spatial resolution with thin slices and small voxel sizes, along with a relatively long echo time (TE) to promote greater phase accumulation. Imaging is performed at higher magnetic field strengths such as 1.5T, 3T, and increasingly 7T MRI systems to improve contrast and signal-to-noise ratio. Additionally, flow-compensated gradients are used to minimize motion-induced phase errors, ensuring more accurate data capture. During the acquisition process, both magnitude images, which provide structural anatomical details, and phase images, which contain susceptibility-related information, are simultaneously recorded and later combined to enhance visualization of venous structures, microbleeds, and iron deposition.

Phase Image Processing

Phase image processing in Susceptibility Weighted Imaging (SWI) is essential because raw phase images contain both meaningful susceptibility information and unwanted background field variations. To address this, preprocessing steps are applied to enhance image quality and accuracy. High-pass filtering is used to remove low-frequency background field effects, such as those caused by large-scale magnetic field inhomogeneities. At the same time, local phase variations arising from tissue susceptibility differences are carefully preserved, as they carry important diagnostic information. Additionally, phase unwrapping techniques are employed to correct discontinuities in phase values, ensuring a smooth and continuous representation of the underlying magnetic field variations for improved interpretation.This step ensures that only clinically relevant susceptibility variations remain.

Generation of Phase Mask

In Susceptibility Weighted Imaging (SWI), a phase mask is generated to selectively enhance regions exhibiting specific susceptibility characteristics, forming a key step in image contrast improvement. This mask emphasizes voxels with negative phase shifts, such as those associated with veins, hemorrhages, or iron deposition, while suppressing voxels that show minimal susceptibility differences. To further improve contrast sensitivity, the phase mask is typically multiplied with the magnitude image multiple times, amplifying the visibility of subtle variations. This masking approach represents the core innovation of SWI, distinguishing it from conventional gradient echo (GRE) imaging by significantly enhancing the detection of susceptibility-based features.

Magnitude and Phase Combination

The final Susceptibility Weighted Imaging (SWI) image is obtained by multiplying the processed phase mask with the magnitude image, effectively combining structural and susceptibility information. The magnitude image contributes detailed anatomical structure, while the phase mask enhances contrast based on magnetic susceptibility differences. This multiplication is often repeated multiple times to further amplify subtle variations, thereby improving the visibility of microstructural features. As a result, the final SWI image provides superior visualization of venous

structures, hemorrhages, and iron deposition, making it highly valuable for clinical diagnosis and research applications.

5.System Architecture of SWI

The Susceptibility Weighted Imaging (SWI) system can be conceptualized as a layered processing architecture that integrates hardware, signal acquisition, reconstruction, and post-processing stages to produce clinically useful images. At the hardware layer, the system includes an MRI scanner operating at field strengths such as 1.5T, 3T, or 7T, along with gradient coils for spatial encoding, RF coils for signal reception, and a high-performance computing unit for data reconstruction. The signal acquisition layer employs a gradient echo pulse sequence generator to capture k-space data in the frequency domain, enabling simultaneous recording of both magnitude and phase signals. In the image reconstruction layer, Fourier transform techniques are applied to convert k-space data into image space, followed by phase correction algorithms and noise reduction filtering to improve image quality. The post-processing layer involves critical steps such as phase unwrapping, high-pass filtering to remove background field variations, phase mask creation, and image multiplication to enhance susceptibility contrast. Finally, the output layer delivers the processed SWI images, with options for advanced outputs like Quantitative Susceptibility Mapping (QSM) and 3D visualization, supporting detailed diagnostic interpretation.

6.Clinical Applications of SWI

Susceptibility Weighted Imaging (SWI) has emerged as a powerful diagnostic tool across multiple medical domains due to its exceptional sensitivity to venous blood, hemorrhage, and iron deposition. In neurovascular imaging, SWI is highly effective in detecting cerebral microbleeds, intracranial hemorrhages, venous malformations, and in assessing conditions such as stroke and ischemia, often revealing early microhemorrhages that are not visible on conventional MRI or CT scans. In neurodegenerative disorders, it plays a crucial role in evaluating abnormal iron accumulation, such as increased iron in the substantia nigra in Parkinson's disease, cortical iron deposition in Alzheimer's disease, and lesion-related susceptibility changes in multiple sclerosis, thereby serving as a useful biomarker for disease progression. SWI is also valuable in traumatic brain injury (TBI), where it enables detection of diffuse axonal injury and small hemorrhagic lesions with greater sensitivity than CT and standard MRI, making it one of the most effective techniques for TBI evaluation.

In oncology, SWI assists in identifying tumor vascularity, detecting intratumoral hemorrhage, and differentiating tumor types based on susceptibility patterns, particularly in gliomas and brain metastases. For vascular disorders, it aids in diagnosing cerebral venous thrombosis, arteriovenous malformations, and abnormal venous drainage patterns, while also enhancing venous contrast without requiring contrast agents. Beyond neuroimaging, SWI has additional applications in detecting liver iron overload, musculoskeletal hemorrhages, and microcalcifications in soft tissues. Overall, SWI provides significant methodological advantages, including high sensitivity to microbleeds and venous blood, non-contrast imaging capability, enhanced detection of iron and calcification, high-resolution 3D structural visualization, and improved diagnostic accuracy, making it a highly valuable technique in modern medical imaging.

7.Results and Discussion

This section presents the performance evaluation, qualitative outcomes, and comparative analysis of Susceptibility Weighted Imaging (SWI) against conventional MRI techniques, focusing on image quality enhancement, lesion detectability, diagnostic sensitivity, and clinical relevance. SWI demonstrates a clear improvement in visualizing susceptibility-related structures when compared with conventional MRI sequences such as T1-weighted, T2-weighted, and Gradient Echo (GRE) imaging. The key qualitative outcomes include enhanced visibility of cerebral microbleeds, improved delineation of venous vasculature, clearer identification of hemosiderin deposits, increased contrast in hemorrhagic lesions, and better detection of iron accumulation in deep brain nuclei. In SWI images, venous structures appear prominently hypointense due to deoxyhemoglobin-induced phase shifts, a feature that is largely absent or significantly less pronounced in standard MRI sequences, thereby enabling superior diagnostic detail and clinical interpretation.

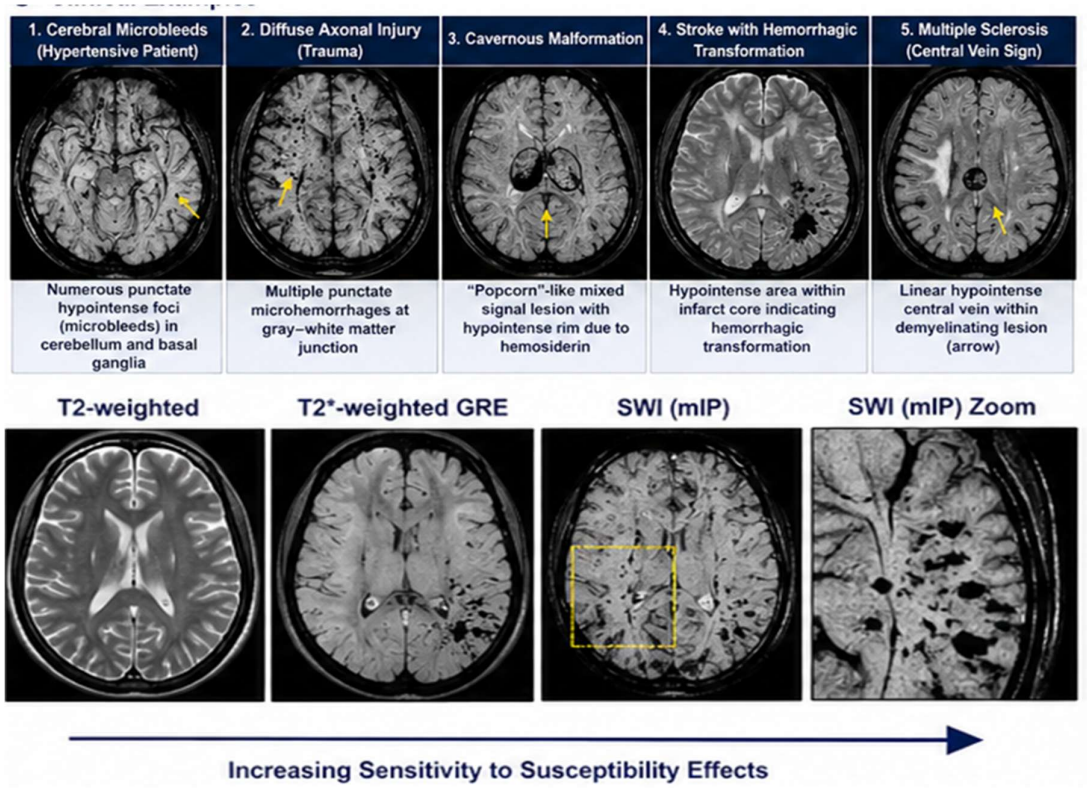


Figure 2 :Comparison Figure (SWI vs T2 / GRE / Conventional MRI)

The following table summarizes the performance comparison between SWI and conventional MRI techniques.

Table 1: Performance Comparision

Feature / Modality	T1-Weighted MRI	T2-Weighted MRI	GRE MRI	SWI
Microbleed Detection	Low	Moderate	High	Very High
Venous Visualization	Poor	Poor	Moderate	Excellent
Iron Sensitivity	Low	Low	Moderate	Very High
Spatial Resolution	Moderate	Moderate	High	Very High
Hemorrhage Detection	Moderate	High	High	Very High
Use of Contrast Agent	Required	Required	Optional	Not Required

SWI demonstrates improved diagnostic performance when evaluated using quantitative metrics such as sensitivity, specificity, signal-to-noise ratio (SNR), and contrast-to-noise ratio (CNR). The sensitivity for detecting microbleeds is approximately 90–95%, while the specificity for hemorrhage detection ranges from 85–92%, indicating strong diagnostic reliability. Additionally, SWI benefits from a significantly higher SNR, particularly at higher magnetic field strengths such as 3T and 7T MRI systems, which enhances image clarity and structural detail. The contrast-to-noise ratio (CNR) is also markedly improved due to the combined use of phase and magnitude information, allowing better differentiation of subtle susceptibility variations. Overall, the increase in both SNR and CNR is primarily

attributed to enhanced susceptibility effects at higher magnetic field strengths, which amplifies the visibility of venous blood, iron deposition, and microhemorrhages.

8.Conclusion

Susceptibility Weighted Imaging (SWI) has emerged as a highly advanced magnetic resonance imaging technique that significantly enhances the visualization of subtle anatomical and pathological changes by exploiting magnetic susceptibility differences in biological tissues. By integrating magnitude and phase information from high-resolution gradient echo sequences, SWI provides superior sensitivity to venous blood, hemorrhage, iron deposition, and calcifications compared to conventional MRI techniques.The review presented in this paper highlights the fundamental physics underlying SWI, including magnetic susceptibility effects, phase behavior, and advanced image reconstruction techniques such as phase masking and magnitude-phase combination. The methodological framework demonstrates how SWI transforms raw MRI data into highly informative diagnostic images through multi-stage processing, including acquisition, phase correction, filtering, and enhancement.

Clinically, SWI has proven to be highly valuable across a wide range of applications, particularly in neurovascular imaging, traumatic brain injury, stroke evaluation, neurodegenerative disorders, and tumor characterization. Its ability to detect cerebral microbleeds and venous abnormalities that are often invisible in standard MRI sequences makes it an indispensable tool in modern neuroradiology.Furthermore, recent advancements such as high-field MRI systems (3T and 7T), Quantitative Susceptibility Mapping (QSM), and the integration of artificial intelligence have significantly expanded the diagnostic and research potential of SWI. These developments are improving image quality, enabling quantitative assessment, and supporting automated disease detection and classification.Despite its advantages, SWI still faces challenges such as susceptibility artifacts, longer acquisition times, and variability in phase interpretation across imaging systems. However, continuous improvements in hardware, computational algorithms, and AI-based reconstruction methods are steadily addressing these limitations.

In conclusion, SWI represents a powerful and evolving imaging modality that bridges the gap between conventional anatomical imaging and advanced functional tissue characterization. With ongoing technological progress, SWI is expected to play an increasingly important role in precision medicine, early disease diagnosis, and advanced neuroimaging research.

References

1. T. Mohana Priya, Dr. M. Punithavalli & Dr. R. Rajesh Kanna, Machine Learning Algorithm for Development of Enhanced Support Vector Machine Technique to Predict Stress, Global Journal of Computer Science and Technology: C Software & Data Engineering, Volume 20, Issue 2, No. 2020, pp 12-20
2. Ganesh Kumar and P.Vasanth Sena, "Novel Artificial Neural Networks and Logistic Approach for Detecting Credit Card Deceit," International Journal of Computer Science and Network Security, Vol. 15, issue 9, Sep. 2015, pp. 222-234
3. Gyusoo Kim and Seulgi Lee, "2014 Payment Research", Bank of Korea, Vol. 2015, No. 1, Jan. 2015.
4. Chengwei Liu, Yixiang Chan, Syed Hasnain Alam Kazmi, Hao Fu, "Financial Fraud Detection Model: Based on Random Forest," International Journal of Economics and Finance, Vol. 7, Issue. 7, pp. 178-188, 2015.
5. Hitesh D. Bambhava, Prof. Jayeshkumar Pitroda, Prof. Jaydev J. Bhavsar (2013), "A Comparative Study on Bamboo Scaffolding And Metal Scaffolding in Construction Industry Using Statistical Methods", International Journal of Engineering Trends and Technology (IJETT) – Volume 4, Issue 6, June 2013, Pg.2330-2337.
6. P. Ganesh Prabhu, D. Ambika, "Study on Behaviour of Workers in Construction Industry to Improve Production Efficiency", International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD), Vol. 3, Issue 1, Mar 2013, 59-66