ABENHA MEDICAL JOURNAL bmj
Print ISSN 1110-208X.
Online ISSN 2357-0016

Original article

The Added Value of Susceptibility Weighted Imaging Compared with Diffusion Weighted Imaging in Assessing Recent Spontaneous Cerebral Hematoma

Mohamed A. Alkenawy [a], Ahmed M. Zidan [a], Mohamed T. Ibrahim [a], Mahmoud M. Fouda [a], Nehal E. Shabaan [b], Yasser F. Ghoraba [b]

[a] Radiology Department, Faculty of Medicine Al-Azhar University, Egypt.

[b] Neurosurgery Department, Faculty of Medicine Tanta University, Egypt.

Corresponding to:
Dr. Mohamed A. Alkenawy. Radiology Department, Faculty of Medicine Al-Azhar University, Egypt. Email: drmohamedalkenawy@gmail.com

Received:
Accepted:

Abstract:

Background: Spontaneous intracerebral hemorrhage (ICH) is a critical condition that still requires early detection, precise staging & comprehensive evaluation of its secondary effects on the cerebral tissue to better guide the clinical & surgical manipulation by using the Up-to-date MRI techniques. **Objectives:** aiming to evaluate the additional benefits of incorporating susceptibility & diffusion-weighted imaging (SWI & DWI) alongside conventional T1, T2 WIs in identifying recent ICH by verifying the degree of correlation in detection and stage evaluation, focusing on the hyper-acute and acute phases, thereby enhancing ICH diagnosis confidence using MRI. **Methods:** a clinically suspected 50 patients to have recent ICH within three days of symptom-onset referred to the radiology department at Al-Hussein Hospital for an urgent CT scan, followed by a comprehensive MRI evaluation that included axial T1, T2, Diffusion, and ADC-map & SWI sequences to better assess the hematoma's condition. The study was conducted from March-2022 to June-2023. **Results:** Our investigation revealed that SWI exhibits higher sensitivity compared to DWI, while combined both techniques enhances sensitivity and accuracy for early ICH detection more effectively than using DWI or SWI in isolation. Additionally, there is no significant statistical disparity in positive predictive value among the three methods. SWI independently proves advantageous in identifying CAA micro bleeds and small cortical hematomas, areas where CT's capabilities usually surpassed. **Conclusion:** The detection rates of ICH were comparable to those of CT scans when SWI and DWI were used together, but the diagnostic value of the combination was higher than that of SWI and DWI used alone.

Keywords: SWI; diffusion WIs; spontaneous cerebral hematoma; CT; ADC.

Introduction

Spontaneous intracerebral hemorrhage (ICH) occurs when blood extravasates to the brain parenchyma without any external injury. Nausea, vomiting, tingling or paralysis in the limbs, and a rise in intracranial pressure are all neurological symptoms that can result from this accumulation [1]. Ischemic cholecystitis (ICH) is the second- most common kind of stroke, and its prevalence is on the rise, with an incidence rate of 1–27 instances per 100,000 persons each year. There has been a significant uptick in cases among younger people, and the disorder has a high fatality rate [2] .

There are serious health risks, severe impairment, and death associated with this disorder, which places a heavy emotional and financial strain on families and communities. Hence, to improve the prognosis of patients with early ICH, it is crucial to recognize hemorrhagic lesions promptly and administer symptomatic treatment appropriately [3,4].

For ICH, CT scans are the way to go. In addition to quickly and accurately pinpointing the location of a hematoma, it can also help evaluate the amount of bleeding, how it has spread inside the ventricles or ventricular membrane, how it has affected surrounding brain regions, and whether any damage has been caused. Nevertheless, there are drawbacks associated with it, including the risk of radiation exposure and the potential for an indistinct visualization of the brainstem and posterior fossa lesions [5].

MRI may provide three-dimensional pictures of the brain, offering several benefits including superior quality, no radiation exposure, and the lack of skull aberrations [6].

An effective and noninvasive magnetic resonance imaging (MRI) technique called diffusion-weighted imaging (DWI) can analyze the movement of water molecules in brain regions to potentially detect hemorrhagic lesions in individuals with early ICH [7]. Clinical studies have shown that DWI has a high potential for misdiagnosis, especially in individuals with neurovascular diseases such vascular brain tumors and cerebral infarction [8].

SWI is an innovative MRI method that relies on the variations in magnetic susceptibilities among different tissues. MRI exhibits a high level of sensitivity towards paramagnetic chemicals, such as deoxyhemoglobin, hemosiderin deposits, and calcium, and possesses a superior ability to detect hemorrhagic & other abnormalities in individuals with early ICH [9,10].

We set out to find hemorrhagic insult signals and determine their stage using both T1 & T2 weighted imaging (WI) signals. Consequently, we planned to confirm the level of agreement in ICH stage assessment using both SWI and DWI. This method examined the efficacy of SWI, DWI, and their combination in verifying the condition during the hyper-acute and acute stages, which had already been diagnosed using conventional CT scans.

Patients and Methods

In our prospective cohort study, we targeted 50 patients suspected of having a recent cerebral hematoma within 3 days of symptom onset, referred to the Al-Hussein Hospital radiology department between March 2022 and June 2023. The diagnosis was made using urgent CT scans, interpreted by three expert radiologists. They defined hyper-acute intracerebral hematoma as a collection of blood within the first 24 hours and acute hematoma as one found within 2-3 days. The exclusion criteria were as follows: patients with trauma, hemorrhagic neoplasms, intracerebral hemorrhage (ICH) occurring more than 3 days after symptom onset, ischemic stroke, contraindications for MRI, recent brain surgery, and other complicated cases.

Examination Methods: Each patient underwent a conventional MRI using a 1.5-T MR scanner (Philips Ingenia, Philips

Healthcare) equipped with a phased-array head coil. The MRI protocol included axial T1, T2, FLAIR, Diffusion, and ADC map sequences, as well as additional SWI sequences in both magnitude and phase contrast images to evaluate the status of the ICH.

The detailed parameters for DWI were as follows: a field of view (FOV) of 20 × 24, a slice thickness of 5.0 mm, slice spacing of 1.0 mm, a repetition time (TR) of 6000 ms, an echo time (TE) of 100 ms, and a b value of 1000 s/mm². For the SWI sequence, the parameters included a slice thickness of 1.2 mm, a matrix size of 256 × 512, a TR of 36 ms, and a TE of 20 ms.

Specifically, SWI's parameters were: The following parameters were used: 5 mm slice thickness, no gap, 230 mm FOV, 35 ms repetition time, 50 ms echo time, 256 x 512 matrix size, 5.15 minutes acquisition time, 15 degrees flip angle, and a head coil.

We aim to highlight the T1 and T2 weighted imaging (WI) signals in the setting of intracerebral hemorrhage (ICH) as our major target. Then, we will assess the hyper-acute and acute stages of ICH using diffusion-weighted imaging (DWI) and susceptibility-weighted imaging (SWI), respectively, to confirm the degree of alignment.

The different signals indicative of a suspected hematoma was identified, and data were collected by three expert radiologists using T1, T2, DWI, ADC, and SWI sequences, then we organized three distinct groups of data sets. Group A consisted of assessments performed by the first radiologist using T1, T2, and DWI sequences for all cases. Group B was established with a different radiologist evaluating all cases using T1, T2, and SWI sequences. Group C included a third radiologist who analyzed the complete protocol, incorporating DWI, SWI, T1, and T2 sequences. The findings from these groups were subsequently compared to the CT results, which acted as the control group.

Informed consent forms were signed by the relatives of all patients. The study received approval from the medical ethics committee at Al-Azhar University (code = 00000043).

Statistical analysis

Statistics were analyzed using SPSS 27 for Windows (IBM SPSS, Inc., Chicago, IL). Parametric quantitative variables were described using mean, SD, and range, while non-parametric variables utilized median and interquartile range. Qualitative variables were reported as No. and %. The independent samples t-test compared continuous variables between groups, while the Chi-square test compared categorical variables. Three groups were compared to the standard CT using a ROC curve. Results were judged non-significant if P-values exceeded 0.05.

Results:

The patients ranged in age range from 46 to 71 years, with a mean age of 61.74 ± SD 4.37. Of the patients, 80% were male and 20% were female. Additionally, 40% of patients were smokers, 90% had hypertension, and 74% had chronic diabetes (Table 1). Of these patients, 40 had ICH and 9 were negative & one case with false negative on CT while positive findings on MRI; positive instances showed a single lesion with an ICH of varying size.

On the first day following the neurological insult, 14% of the cases were received, On the second day, this percentage increased to 20%, while on the third day, 66% of the total number of cases were received (as shown in Table 2).

In an initial study of 50 cases, computed tomography scans revealed hyperacute and acute hemorrhage in 40 of the cases, with only 1 showing atypical findings attributed to anemia. The remaining 9 cases showed no signs of hemorrhage.

DOI: 10.21608/bmfj.2025.324677.2211

Table (1): Distributions of demographic data & risk factors in the studied group.

Parameters	Studied group (N=50)
Age (years)	Mean ± SD: 61.86 ± 4.92
Gender	Male: 80% & Female:20%
Smoking	Negative:60%, Positive: 40%
Hypertension	Negative:10%, Positive: 90%
Diabetes	Negative:26%, Positive: 74%

Table (2): Distribution of hemorrhagic lesions among days of scan in the studied group.

Parameters	Studied group(N=50)
First-day cases: N (%)	7 (14%)
Second-day cases: N (%)	10 (20%)
Third -day cases: N (%)	33 (66%)

The examination of the independence of hypertension, diabetes, and smoking in relation to the outcomes of CT exams for hematoma detection was conducted using the chi-square test (Table 3). The results indicated a positive association between hypertension and diabetes and the presence of hematoma on CT scans. On the other hand, a higher p-value was observed in the case of smoking, suggesting the lowest affection of smoking as a risk factor among the examined parameters in our study.

There were additional observations made during the assessment and validated through Susceptibility-weighted imaging (SWI), such as white matter abnormalities in the form of patchy abnormal peri-ventricular foci of small vessel disease, scattered signal void foci with blooming in SWI representing microbleeds, and a combination of both. The study aimed to illustrate the distribution of these findings among the examined cases. It is noteworthy that 16% of cases displayed changes related to small vessel disease, while 10% had microbleeds only and 10% exhibited a combination of both. The remaining 60% of cases showed no associated findings. Two cases in our study, representing 4% of the examined cases, had an atypical finding of a hypodense area on CT, while also displaying evidence of hemorrhage signals in both Diffusion-weighted imaging (DWIs) and SWI, and were linked to anemia.

Table (3): Use of the chi-square test in detecting the relationship between hypertension and the presence of hemorrhage in CT.

Parameters	Studied group(N=50)
Hypertension	P-value=0.001
Diabetes	P-value=0.002
Smoking	P-value=0.087

Table (4): the distribution of the incidental findings noted in the examined cases.

Parameters	**Studied group(N=50) (frequency/ percent)**
Small vessel disease	8 16%
Microbleeds of amyloid A	5 10%
Combination of both	5 10%
No incidental findings	31 62%
Isodense lesion in anemia	1 2%

Out of fifty patients who were scanned, initial CT scans revealed hyperdense bleeding in forty cases and no hemorrhage in ten. Groups A, B, and C had their bleeding detection rates evaluated with CT as a reference. Negative predictive values varied, becoming high in group C and low in group A, whereas positive predictive values were not significantly different among the three groups. In addition, group C had a higher sensitivity (up to 100) than groups B (95%), A (90%), and C (99%), but all three groups showed good specificity (up to 90%), and there was hardly any difference in specificity between them in this study (Table **5**).

The Receiver Operating Characteristic (ROC) Curve was employed to establish correlations between the three groups and the CT findings. It revealed a comparatively greater area under the curve for group C (0.950), a relatively lower area for group B (0.925), and the smallest area for group A (0.900), while also extracting measures of sensitivity, specificity, positive predictive value, and negative predictive value.

Table (5): Identification of early ICH based on 1.5 Tesla MRI parameters.

Parameters	**Frequency**	**Sensitivity**	**Specificity**	**Sensitivity 95% CI**	**+PV**	**-PV**
Group A DWI	Positive = 37 Negative = 12	90 %	90 %	76.3 - 97.2	97.3%	69.2
Group B SWI	Positive = 39 Negative = 10	95%	90%	83.1 - 99.4	97.4%	81.8
Group C Combined DWI&SWI	Positive = 40 Negative = 9	100 %	90%	91.2 - 100.0	97.6	100.0

CT Findings: Positive = 40, Negative = 9 cases, Excluded false Negative =1.

DOI: 10.21608/bmfj.2025.324677.2211

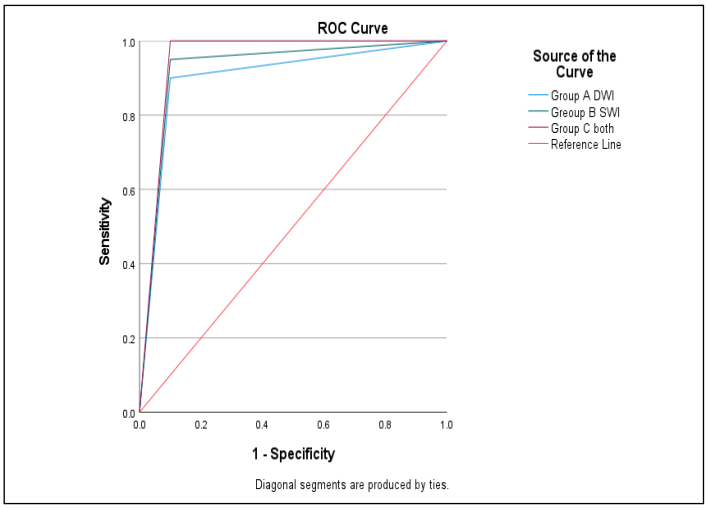

Figure (1): *ROC curve* showing the three groups plotted over the reference line compared to the CT results.

Within the initial 24 hours following the onset of neurological insult, the imaging features observed in diffusion-weighted imaging (DWI) and susceptibility-weighted imaging (SWI) reveal distinctive patterns. In early cases, isointense signals on T1-weighted images (T1 WIs) are noted, accompanied by T2 signals ranging from intermediate to faintly high, and a hyperintense rim, alongside a mildly hyperintense center on DWIs, with corresponding low values on the apparent diffusion coefficient (ADC) maps. Concurrently, SWI exhibits intermediate to bright signals at the center and low signals at the periphery, while a combination of signals becomes more apparent later in the first day, aligning with the transition from hyperacute to acute stages. Notably, a thin hyperintense rim is discernible in the DWI and ADC map images, particularly evident in high B values, which widens in acute cases (refer to Figure 2).

On the subsequent day of cases, the manifestations evolved into an acute phase characterized by consistent isointense signals on T1-weighted imaging, intermediate to low signals on T2-weighted imaging with a hyperintense rim, results on diffusion-weighted imaging (DWI) and lower apparent diffusion coefficient (ADC) maps are typically indicative of poor signals. It was also clear that there was a prominent ring of brilliant signals around the periphery. In addition, the susceptibility-weighted imaging (SWI) magnitude pictures showed a hyperintense ring and significantly reduced signals at the center of the lesion, along with blooming artifact.

By the third day of observation, comparable signal patterns persisted, characterized initially by ongoing isointense signals on T1-weighted images (T1 WIs), along with diminished signals on diffusion-weighted imaging (DWI) and lower values on the apparent diffusion coefficient (ADC) map. Moreover, susceptibility-weighted imaging (SWI) signals remained markedly diminished, with a distinct peripheral hyperintense rim evident (see Figure 3). Additionally, T2-weighted images (T2 WIs) increasingly trended towards lower signal intensities.

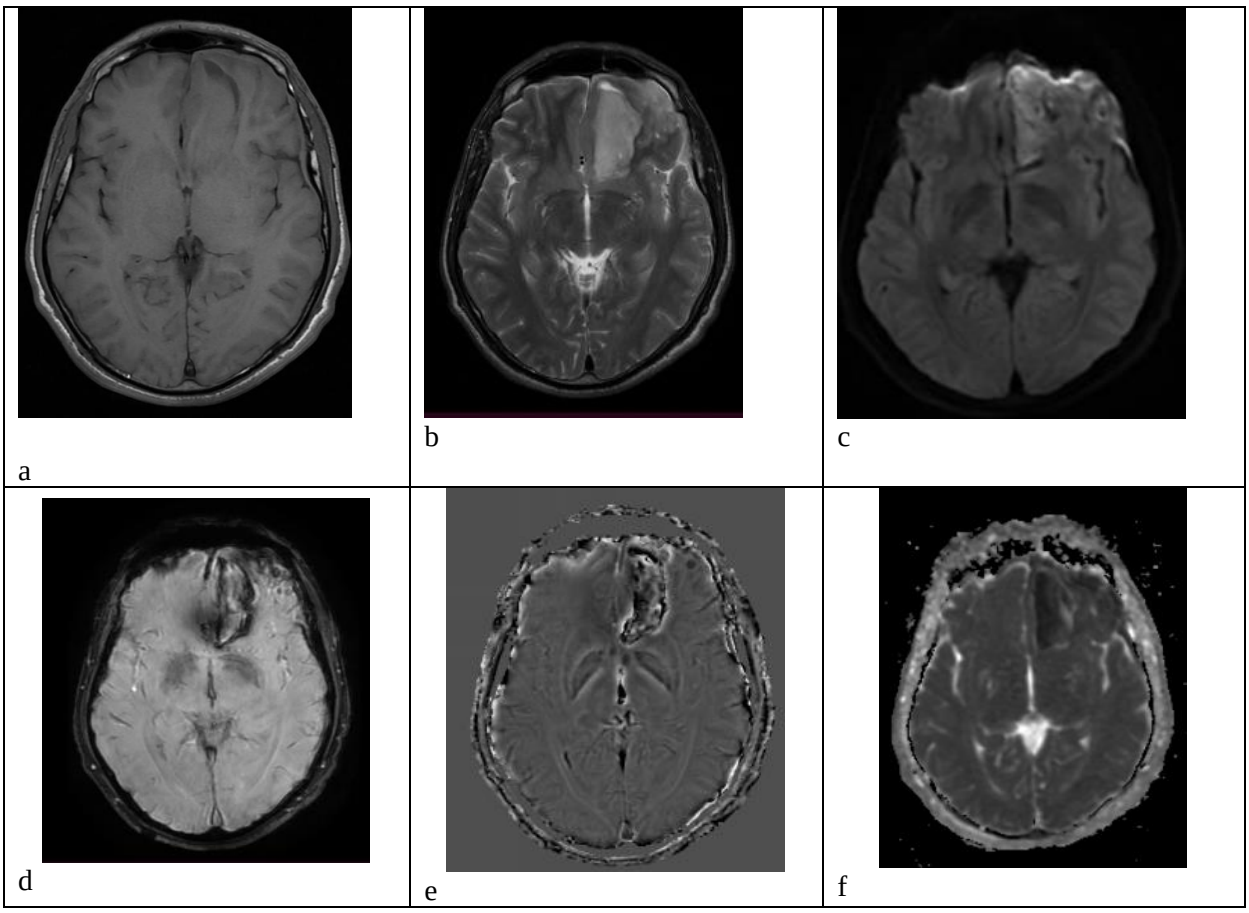

Figure (2): Demonstrates *hyperacute* left frontal parasagittal hematoma with image (a) points to T1 with isointense signals, (b)T2 WI image with bright signals (c) bright signal at DWI with low rim as well (f)the corresponding low signals at ADC map, (d) the SWI images with bright center & low signals and blooming at margin while (e) the corresponding phase contrast image.

The findings of our study revealed a heightened sensitivity of susceptibility-weighted imaging (SWI) in contrast to diffusion-weighted imaging (DWI) for the detection and staging of intracerebral hemorrhage (ICH), with further enhanced sensitivity observed upon combining both imaging modalities and correlating their findings with those of T1 and T2 sequences. Additionally, we observed a consistently high specificity across all three imaging groups, with negligible disparities among them. Although no statistically significant variance was noted in the positive predictive values among the three groups, they all demonstrated high levels. Notably, substantial disparities were observed in the negative predictive values. Our observations underscore the superior sensitivity and accuracy achieved through the concurrent utilization of DWI and SWI, surpassing the diagnostic efficacy of either modality alone in the early detection of ICH.

DOI: 10.21608/bmfj.2025.324677.2211

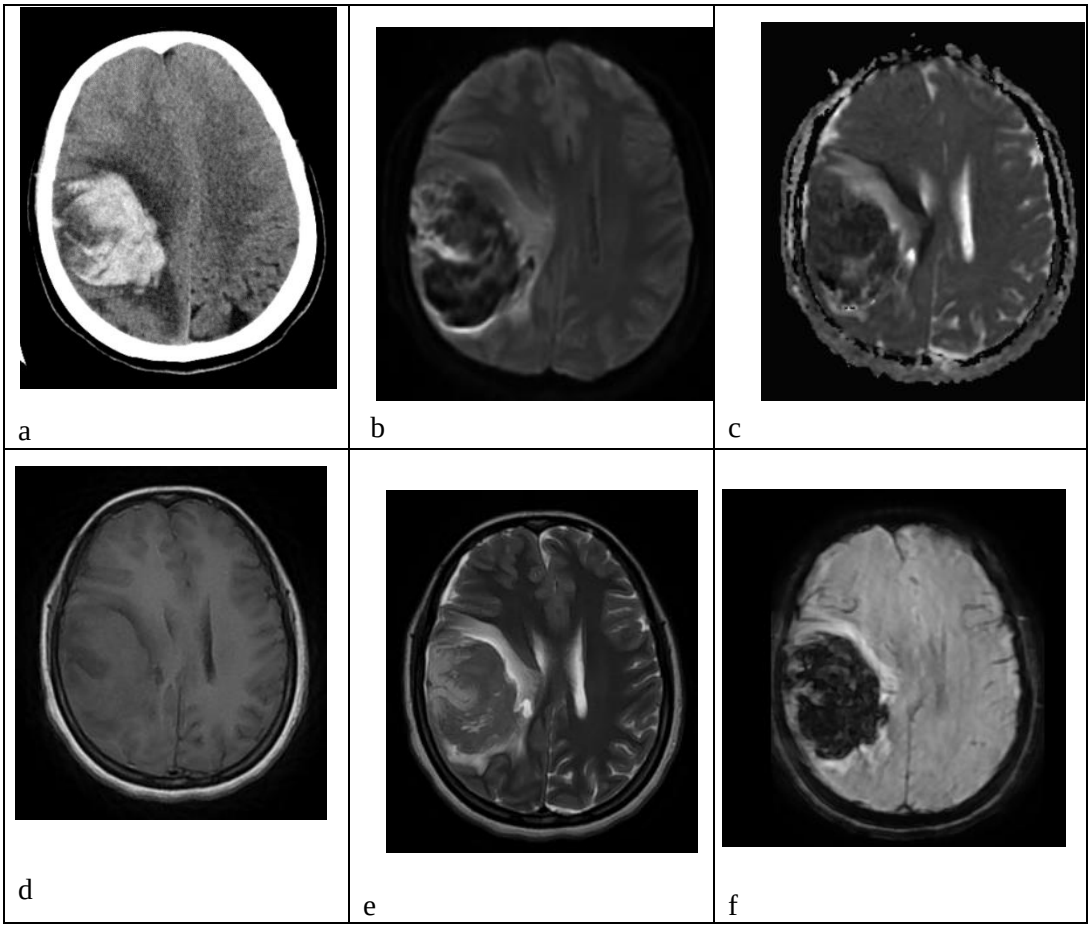

Figure (3) demonstrates ***acute*** right front-parietal subcortical & deep hematoma with image (a) points to CT hyperdense appearance (b) marked low signal at DWI with bright rim as well (c)the corresponding low signals at ADC map, (d) T1 with isointense signals (e)T2 image with low signal center and bright rim, finally (f) the SWI images with marked low signals and blooming.

Discussion

The use of SWI sequences in routine medical practice is on the rise. As an adjunct to more conventional magnetic resonance imaging (MRI) procedures, it may provide useful information. When it comes to detecting intracranial blood products, SWI is more sensitive than T2* methods [11, 12]. The ability of SWI can detect microbleeds and other advanced-stage blood products with great sensitivity and resolution is largely responsible for its popularity. Microbleeds and advanced-stage blood products are the main indications for SWI's use. This is especially true in trauma patients or those with amyloid angiopathy, microbleeds, and superficial siderosis. A common misconception is that all bleeds appear black on SWI. This is since microbleeds and late-stage blood products do appear black. Different phases of ICH can be identified by the shifting levels of signal intensity on T1- and T2-weighted MR images [13-15].

The identical mechanisms that result in these alterations in signals also give rise to the inconsistent manifestations of aging blood on SWI [16]. These factors can result in ambiguity, misrepresentation, and eventually an incorrect diagnosis. For example, the specific features of hyperacute bleeding might be perplexing, particularly when there is no clinical suspicion of hemorrhage. In addition, there are additional pathological conditions that

might resemble ICH because they can look partially or completely dark on SWI.

In both venous and arterial hemorrhages, oxyhemoglobin is the main contributor to the MRI signal during the hyperacute phase. Due to its diamagnetic nature and absence of unpaired electrons, oxyhemoglobin has negligible T2* effects and a little reduction in the T1 relaxation period. Therefore, a medium to strong signal on SWI is produced by these diamagnetic qualities and the lack of paramagnetic effects [(12)].

Clot formation diminishes the extracellular space, leading to restricted diffusion that is most evident at the clot's core [(17)]. Conversely, deoxyhemoglobin formation occurs at the periphery of the intracerebral hemorrhage (ICH) shortly after onset, producing a low signal rim on susceptibility-weighted imaging (SWI). Furthermore, clot formation decreases free water content, which in turn reduces T1 and T2 relaxation times, ultimately resulting in isointense T1 signals [(18)].

In the acute phase, the hematoma is surrounded by paramagnetic deoxyhemoglobin as the continuous conversion of oxyhemoglobin continues. As a result, on susceptibility-weighted imaging (SWI), the signal is consistently weak throughout the hematoma. Also, on both the b1000 and the apparent diffusion coefficient (ADC) images, diffusion-weighted imaging (DWI) shows that the hematoma has a low signal. Because paramagnetic deoxyhemoglobin causes a very weak T2 signal on B0 pictures, this phenomenon—called the T2-blackout effect—occurs [(17)].

Rather than reflecting actual diffusion restriction, the weak signal seen on ADC images is a consequence of signal attenuation caused by susceptibility effects. Similar to the hyperacute stage, the decreased free water content within the ICH is shown by the isointense T1 signal. The strong paramagnetic effects of deoxyhemoglobin, on the other hand, considerably reduce the T2 signal [(19)].

Our findings corroborated the study conducted by Song et al. [(20)], which sought to examine the diagnostic efficacy of combining SWI with DWI for early ICH. Their dataset consists of 61 individuals who were diagnosed with early ICH using CT scans. Out of the total cases, 44 exhibited a single hemorrhagic lesion, and 17 cases had two lesions, resulting in a total of 78 detected lesions. The sensitivity of DWI was found to be 92.30%, with a positive predictive value (PPV) of 100%. SWI demonstrated a sensitivity of 94.87% and a PPV of 100%. When combining both techniques, the sensitivity and PPV achieved 100%. However, there is a discrepancy in the interpretation of SWI signals during the hyperacute stage. Contrary to prior descriptions indicating a very low signal intensity in the first 6 hours at the center of the hematoma, our findings are consistent with those of Weerink LBM et al. [(19)], who observed that SWI signals in the hyperacute stage range from intermediate to high intensity very early on the insult & subsequently decreasing over time.

Ling et al. [(21)] conducted a study to determine the pattern of signal changes in intracerebral hemorrhage using SWI at different phases, in comparison to T1-weighted imaging (T1WI) & T2-weighted imaging (T2WI). The researchers conducted a retrospective evaluation of a group of 365 patients who received T1WI, T2WI, & SWI examinations either at the same time or one after the other from 2015 to 2017, concluded a varied appearance of the SWI correlated with T1 and T2 WIs signals with strong relation and moderate consistency between the signal intensity of intracerebral hemorrhage on T2 and SWI.

We found no statistically significant difference between the three groups in terms of their positive predictive value. Our results show that when comparing DWI and SWI for early ICH detection, the combined results are more accurate, specific, and sensitive than either method alone.

DOI: 10.21608/bmfj.2025.324677.2211

Song et al. [20] demonstrated that the combination of SWI & DWI confirms a higher diagnostic value & accuracy for early ICH diagnosis in Chinese cases compared to SWI & DWI alone while achieving comparable detection rates to CT scans. Our findings corroborate these results.

In addition, Li et al. [22] determined that SWI may be utilized to provide guidance for personalized thrombolytic treatments and aid doctors in making much more informed judgments by carefully considering the advantages and disadvantages. Nevertheless, there are still ongoing debates regarding the correlation between symptoms on SWI & thrombolytic treatment.

Numerous investigations have demonstrated that SWI outperforms T2-weighted sequences in the detection of cerebral microbleeds CMB [23- 25].

One of the significant advantages of high-resolution SWI is its exceptional sensitivity to intracranial hemorrhages, including micro-hemorrhagic foci. This sensitivity, coupled with superior image quality, makes it highly effective in the early diagnosis of cerebral amyloid angiopathy (CAA) accompanied by cerebral microbleeds (CMB), which may be linked to intracerebral hemorrhage (ICH). Consequently, SWI holds substantial diagnostic value and has the potential to become the preferred modality for the early detection of CAA [26].

Furthermore, the combination of SWI and DWI not only achieves a high rate of detection, but also effectively addresses the drawbacks of CT scans, such as the potential for radiation exposure and the presence of skull artifacts. Additionally, research has demonstrated that SWI MRI sequences have the potential to enhance the identification of smaller lesions in certain cases, beyond the capabilities of CT scans. This improvement in detection might be particularly useful in the early stages of ICH [27- 29].

We recommend incorporating SWI alongside DWI in the routine evaluation of neurological diseases, particularly in cases where hemorrhage is suspected and in older, diabetic, and hypertensive patients at risk of cerebral amyloid angiopathy (CAA) for the detection of microbleeds. Further research is required to explore and expand the potential applications of SWI in both clinical practice and research within the field of neuroradiology.

Conclusion

We concluded that SWI offers numerous advantages for making more informed clinical decisions by enhancing the detection and staging of recent ICH, demonstrating higher sensitivity and specificity compared to DWI alone. When both techniques are correlated with T1 and T2-weighted imaging signals, they can achieve results comparable to CT, with high sensitivity and specificity. SWI alone is particularly valuable for confirming the hyperacute blood differing it from other neoplastic possibility & also detecting the frequently associated microbleeds of CAA. In combination with DWI, it effectively depicts small vessel disease, surpassing the capabilities of CT. Additionally, patients who are contraindicated for CT, such as expected pregnant women and individuals with minor early lesions, may benefit from a combined examination utilizing SWI and DWI.

Limitations

Among the potential limitations of our study is the small sample size, as well the MRI scan time that presents a significant limitation in emergency cases, particularly regarding motion artifacts in unconscious patients, other risk factors couldn’t be assessed.

Data Availability

The data used to support the study findings are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

1. Shinar S, Harris K, Van Mieghem T, Lewi L, Morency AM, Blaser S, *et al*. Early imaging predictors of fetal cerebral ischemic injury in monochorionic twin pregnancy complicated by spontaneous single intrauterine death. Ultrasound in Obstetrics & Gynecology. 2022 Apr;59(4):497-505.
2. Ikram A, Sharma R, Selim M, Kim-Sun G, Shahraki T, Thomas AJ, et al. mcTFI QSM MRI ABC/2 intracranial hemorrhage to noncontrast head CT volume measurement equivalence. Journal of the Neurological Sciences. 2024 Jan 15; 456:122859.
3. Knight RA, Nagaraja TN, Li L, Jiang Q, Tundo K, Chopp M, et al. A prospective safety trial of atorvastatin treatment to assess rebleeding after spontaneous intracerebral hemorrhage: a serial MRI investigation. Austin journal of cerebrovascular disease & stroke. 2016;3(1).
4. Kidwell CS, Saver JL, Mattiello J, Warach S, Liebeskind DS, Starkman S, et al. Diffusion-perfusion MR evaluation of perihematomal injury in hyperacute intracerebral hemorrhage. Neurology. 2001 Nov 13;57(9):1611-7.5
5. Ridha M, Megjhani M, Nametz D, Kwon SB, Velazquez A, Ghoshal S, et al . Suboptimal Cerebral Perfusion is Associated with Ischemia After Intracerebral Hemorrhage. Neurocritical Care. 2023 Nov 13:1-0.
6. Shams S, Martola J, Cavallin L, Granberg T, Shams M, Aspelin P, et al. SWI or T2*: which MRI sequence to use in the detection of cerebral microbleeds? the karolinska imaging dementia study. AJNR Am J Neuroradiol 2015; 36: 1089–95.
7. Doumbe J, Abdouramani K, Gams DM, Ayeah CM, Kenmegne C, Mapoure YN. Spontaneous intracerebral hemorrhage: epidemiology, clinical profile and short-term outcome in a tertiary hospital in Sub-Saharan Africa. World Journal of Neuroscience. 2020 Aug 5;10(3):141-54.
8. X. Xie, Y. Liang, and S. Zhan, "Value of high field intensity MRI DWI combined with SWI sequence in the diagnosis of acute cerebral hemorrhage," Chinese Journal of CT and MRI, vol. 18, no. 1, pp. 1–3, 2020.
9. S. Tian, X. Rui, and W. J. Chen, "Cerebral hemorrhage multiphase phase evolution law and MRI signal characteristics," Chinese Journal of CT and MRI, vol. 16, no. 8, pp. 11–14, 2018.
10. Zhao S., Zhang C. Correlation between the presence or absence of residual encephalomalacia after hypertensive cerebral hemorrhage on CT and SWI imaging manifestations. *Journal of China Clinic Medical Imaging.* 2020;31(1):61–63.
11. Schelhorn J, Gramsch C, Deuschl C, Quick HH, Nensa F, Moenninghoff C, et al. Intracranial hemorrhage detection over time using susceptibility-weighted magnetic resonance imaging. Acta Radiol 2015; 56: 1501–7.
12. Gomori JM, Grossman RI. Mechanisms responsible for the MR appearance and evolution of intracranial hemorrhage. Radiographics 1988; 8: 427–40.
13. Bradley WG. MR appearance of hemorrhage in the brain. Radiology 1993; 189: 15–26.
14. Parizel PM, Makkat S, Van Miert E, Van Goethem JW, van den Hauwe L, De Schepper AM. Intracranial hemorrhage: principles of CT and MRI interpretation. Eur Radiol 2001; 11: 1770–83.
15. Weerink LB, Appelman AP, Kloet RW, Van der Hoorn A. Susceptibility-weighted imaging in intracranial hemorrhage: not all bleeds are black. The British journal of radiology. 2023 Jul 1;96(1148):20220304.
16. Salmela MB, Krishna SH, Martin DJ, Roshan SK, McKinney AM, Tore HG, et al. All that bleeds is not black: susceptibility weighted imaging of intracranial hemorrhage and the effect of T1 signal. Clin Imaging 2017; 41: 69–72.
17. Silvera S, Oppenheim C, Touzé E, Ducreux D, Page P, Domigo V, et al. Spontaneous intracerebral hematoma on diffusion-weighted images: influence of T2-shine-through and T2-blackout effects. AJNR Am J Neuroradiol 2005; 26: 236–41.
18. Yoon I, Slesinger TL. Radiation Exposure In Pregnancy. In: Stat Pearls. Stat Pearls Publishing, Treasure Island (FL); 2023. PMID: 31869154.
19. Weerink LBM, Appelman APA, Kloet RW, Van der Hoorn A. Susceptibility-weighted imaging in intracranial hemorrhage: not all bleeds are black. Br J Radiol. 2023 10.1259/bjr.20220304.
20. Song Z, Peng J, Li X, Shen G. Diagnostic Value of Susceptibility-Weighted Imaging Combined with Diffusion-Weighted Imaging in Early Intracerebral Hemorrhage. Contrast Media & Molecular Imaging. 2022 Jun 24;2022.
21. Liang JJ, Lei L, Zeng YP, Xiao ZM. High signal-intensity abnormalities in susceptibility-weighted imaging for primary intracerebral hemorrhage. International Journal of Neuroscience. 2019 Sep 2;129(9):842-7.
22. Li L, Liu MS, Li GQ, Zheng Y, Guo TL, Kang X, et al . Susceptibility-weighted imaging in thrombolytic therapy of acute

DOI: 10.21608/bmfj.2025.324677.2211

ischemic stroke. Chinese medical journal. 2017 Oct 20;130(20):2489-97.
23. Wycliffe ND, Choe J, Holshouser B, Oyoyo UE, Haacke EM, Kido DK. Reliability in detection of hemorrhage in acute stroke by a new three-dimensional gradient recalled echo susceptibility-weighted imaging technique compared to computed tomography: A retrospective study J Magn Reson Imaging. 2004;20:372–7.
24. Santhosh K, Kesavadas C, Thomas B, Gupta AK, Thamburaj K, Kapilamoorthy TR. Susceptibility weighted imaging: A new tool in magnetic resonance imaging of stroke Clin Radiol. 2009;64:74–83.
25. Tong KA, Ashwal S, Holshouser BA, Shutter LA, Herigault G, Haacke EM, et al Hemorrhagic shearing lesions in children and adolescents with posttraumatic diffuse axonal injury: Improved detection and initial results Radiology. 2003;227:332–9 .
26. Cheng Ma, Yumei Wang, Li Liu, Qingtao Ma, Ming Yang, Xiaodong Li, et al.The diagnostic value of high-resolution, susceptibility-weighted imaging for cerebral amyloid angiopathy with cerebral microbleed. In Int J Clin Exp Med, ijcem. 2020; 13- 2.
27. Greenberg SM, Vernooij MW, Cordonnier C, Viswanathan A, Salman RA, Warach S, et al. Cerebral microbleeds: a guide to detection and interpretation. The Lancet Neurology. 2009 Feb 1;8(2):165-74.
28. Nandigam RN, Viswanathan A, Delgado P, Skehan ME, Smith EE, Rosand J, et al. MR imaging detection of cerebral microbleeds: effect of susceptibility-weighted imaging, section thickness, and field strength. American Journal of Neuroradiology. 2009 Feb 1;30(2):338-43.
29. Atlas SW, Thulborn KR. MR detection of hyperacute parenchymal hemorrhage of the brain. AJNR Am J Neuroradiol 1998; 19: 1471–77.

To cite this article: Mohamed A. Alkenawy, Ahmed M. Zidan, Mohamed T. Ibrahim, Mahmoud M. Fouda, Nehal E. Shabaan , Yasser F. Ghoraba. The Added Value of Susceptibility Weighted Imaging Compared with Diffusion Weighted Imaging in Assessing Recent Spontaneous Cerebral Hematoma. BMFJ XXX, DOI: 10.21608/bmfj.2025.324677.2211.