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Susceptibility-Weighted Imaging in the Evaluation of Cerebral Microbleeds in Hypertensive and Normotensive Patients.

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Abstract

Background: Susceptibility-weighted imaging (SWI) is more sensitive than gradient-recalled echo sequences for detecting cerebral microbleeds (CMBs), small paramagnetic deposits that mark underlying cerebral small-vessel disease. Their prevalence and distribution across hypertensive and normotensive patients in routine clinical MRI practice remain incompletely characterised. Objectives: To identify cerebral microbleeds on SWI in patients undergoing brain MRI, to compare their occurrence between hypertensive and normotensive patients, and to relate blooming on SWI to associated white-matter ischaemic change. ***Methods***: This descriptive cross-sectional study enrolled 100 patients referred for brain MRI at a tertiary-care centre over a -12 month period, on a 1.5 T scanner (conventional sequences plus SWI). Demographic, clinical and imaging variables were tabulated, and the association between acute infarction and SWI blooming was tested using the chi-square test. ***Results***: The cohort was predominantly middle-aged to elderly (41-60 years, 40%; 61-80 years, 38%) and male (69%). Weakness (37%) and headache (31%) were the commonest presenting symptoms, and 47% of patients had a documented history of hypertension. Chronic small-vessel ischaemic change was the leading conventional MRI finding (30%), followed by acute infarction (18%). SWI blooming was most frequent in the temporal (36%), frontal (31%), parietal (26%) and occipital (24%) lobes; 20% of patients showed no blooming. Blooming did not differ significantly between patients with and without acute infarction (72/112 vs. no distinct group difference; chi-square, p = 1.0), suggesting that microbleed-related susceptibility change largely reflects chronic microvascular injury rather than acute infarction alone. ***Conclusion***: SWI identifies microvascular haemorrhagic change that is frequently missed on conventional sequences, in hypertensive and normotensive patients alike. Its routine inclusion in brain MRI protocols may improve detection of cerebral small-vessel disease and support risk stratification, although larger, longitudinal studies using standardised microbleed-rating scales are needed to establish its prognostic value.

Keywords: susceptibility-weighted imaging; cerebral microbleeds; hypertension; cerebral small-vessel disease; magnetic resonance imaging.

INTRODUCTION

Cerebral microbleeds (CMBs) are small, chronic deposits of blood-breakdown products that accumulate around structurally fragile small vessels.[1] Their radiological conspicuity depends on echo time, spatial resolution and static magnetic field strength: as field strength rises and voxel size falls, the paramagnetic “blooming” effect around these deposits becomes more pronounced, improving detection sensitivity. In clinical practice, both gradient-recalled echo (GRE) and susceptibility-weighted imaging (SWI) sequences are used to identify microbleeds, but SWI is generally preferred because of its superior inter-rater reliability and greater sensitivity for CMB detection.[1]

Visual scoring systems such as the Microbleed Anatomical Rating Scale (MARS) and the Brain Observer MicroBleed Scale (BOMBS) classify microbleeds by anatomical location (infratentorial, deep, or lobar) and by diagnostic certainty. Automated and semi-automated post-processing methods, including deep-learning-based detection on SWI, are increasingly used alongside these visual scales to improve reproducibility.[4,5] Microbleeds are recognised markers of

cerebral small-vessel disease and have been linked to cognitive decline, stroke risk and overall mortality, making their detection clinically relevant well beyond the acute stroke setting.[2,3]

Hypertension is among the most important modifiable risk factors for small-vessel disease and is closely associated with the arteriopathic changes that predispose to microbleed formation.[7] However, microbleeds are also seen in normotensive patients, particularly in the context of cerebral amyloid angiopathy or other vasculopathies, indicating that hypertensive status alone does not fully account for their occurrence.[8] This study was undertaken to characterise CMBs on SWI in a routine tertiary-care MRI cohort, to compare their occurrence between hypertensive and normotensive patients, and to examine their relationship with associated ischaemic change.

1.1 Aims and Objectives

Aim: To assess the role of the SWI sequence on brain MRI in detecting cerebral microbleeds and to correlate these findings with clinical history.

Objectives:

- To identify cerebral microbleeds on susceptibility-weighted MRI.
- To compare the occurrence of cerebral microbleeds between hypertensive and normotensive patients.
- To correlate cerebral microbleeds with white-matter ischaemic change in hypertensive patients.

MATERIALS AND METHODS

Study design and setting: This was a descriptive cross-sectional study conducted in the Department of Radiodiagnosis, Teritiary Care Teaching Hospital , over a 12-month period . One hundred patients were enrolled.

Study population: Patients referred for brain MRI with clinical features suggestive of hypertension, and patients in whom cerebral microbleeds were detected incidentally on brain MRI performed for other indications, were eligible. Normotensive patients of varying ages referred for brain MRI for unrelated indications served as comparators.

Inclusion criteria: (i) patients with a clinical history of hypertension; (ii) patients with incidentally detected cerebral microbleeds on brain MRI; (iii) normotensive patients of different age groups referred for brain MRI for other indications. Exclusion criteria: Patients with standard contraindications to MRI, including ferromagnetic implants, cardiac pacemakers, or claustrophobia, were excluded.

Imaging protocol: All examinations were performed on a 1.5 T Philips Achieva d-stream MRI scanner using a standard brain protocol supplemented with an SWI sequence.

Statistical analysis: Categorical variables were summarised as frequencies and percentages. The association between acute infarction and SWI blooming was assessed using the chi-square test, with $p < 0.05$ taken as statistically significant.

RESULTS

A total of 100 patients were evaluated. The demographic and clinical characteristics of the cohort are summarised in Table 1.

Table 1. Demographic and clinical profile of the study population (n = 100)

Variable	Category	n (%)
Age (years)	21-40	15
	41-60	40
	61-80	38
	>80	6
Sex	Male	69
	Female	31
History of hypertension	Present	47
	Absent	53

Weakness (37%) and headache (31%) were the most frequent presenting symptoms; less common presentations included mouth deviation (10%, predominantly left-sided), old cerebrovascular accident (8%), Parkinsonian features (5%), post-traumatic presentation (road traffic accident 5%, head injury 2%), seizures (3%), demyelinating disease (3%), facial palsy (1%) and hypertensive emergency (1%).

Table 2. Conventional MRI findings

Finding	n (%)
Chronic small-vessel ischaemic change	30
Acute infarct	18
Subacute infarct	9
Chronic infarct	9
Tumour / space-occupying lesion	9
Haemorrhage / haemorrhagic transformation	5
T2/FLAIR hyperintensity (demyelination)	3
Diffuse axonal injury / contusion	2
Features of raised intracranial pressure	2
Empty sella	2
No acute abnormality	17

On SWI, blooming attributable to microbleeds and related susceptibility effects was most frequent in the temporal lobe, followed by the frontal, parietal and occipital lobes (Table 3). Twenty percent of patients showed no blooming on SWI.

Table 3. Regional distribution of blooming on SWI

Region	n (%)
Temporal lobe	36
Frontal lobe	31
Parietal lobe	26
Occipital lobe	24
Cerebellum	22
Corona radiata / centrum semiovale	16
Thalamus	12
Basal ganglia	8
Brainstem / pons / substantia nigra	3
Periventricular white matter / insular cortex	2
No blooming	20

There was no statistically significant association between the presence of acute infarction and SWI blooming (chi-square test, p = 1.0; Table 4), indicating that blooming on SWI more often reflects chronic microvascular change than acute infarction alone.

Table 4. Association between acute infarct and SWI blooming

	Blooming present	No blooming	Total
Acute infarct	32	18	50
No acute infarct	40	22	62
Total	72	40	112

Symptom-imaging correlation showed that weakness was strongly associated with acute infarction, mouth deviation with acute infarction affecting the corticobulbar pathway, Parkinsonian features with chronic ischaemic change, and post-traumatic presentations with haemorrhage or normal imaging. Headache and seizures were non-specific, occurring across a broad range of imaging findings including chronic ischaemia, tumours and normal studies.

DISCUSSION

This study characterised the pattern of SWI-detected microbleed-related blooming in a tertiary-care cohort undergoing brain MRI for a range of neurological indications, and related these findings to conventional imaging and clinical presentation. Consistent with the established role of hypertension as a driver of cerebral small-vessel disease, nearly half of the cohort (47%) had a documented history of hypertension, and chronic small-vessel ischaemic change was the single most common conventional MRI finding (30%). The predominance of patients in the 41-60 and 61-80 year age bands is in keeping with the age-dependent accumulation of small-vessel pathology, while the male predominance (69%) may reflect a combination of vascular risk-factor prevalence, referral patterns and health-seeking behaviour rather than a purely biological effect. Blooming on SWI was most frequent in the temporal and frontal lobes, with additional involvement of the parietal and occipital lobes, cerebellum, and deep grey and white matter structures. This distribution is broadly consistent with regions vulnerable to small-vessel arteriopathy and, in a subset of patients, posterior circulation involvement. Notably, blooming was seen in a similar proportion of patients with and without acute infarction, and the association between the two was not statistically significant (p = 1.0).

This finding, in agreement with reports that venous and microvascular structural change contributes to microbleed formation independent of acute ischaemic events,[6] supports the interpretation that SWI-detected blooming chiefly reflects chronic microvascular injury—deoxyhaemoglobin, haemosiderin or other paramagnetic deposition—rather than serving as a marker of acute infarction alone. Importantly, microbleeds were not confined to hypertensive patients. Case-level

evidence indicates that patients without hypertension, including those with cerebral autosomal dominant/recessive arteriopathies such as CADASIL, may harbour multiple microbleeds detectable on SWI before any haemorrhagic event occurs.[8] This reinforces the value of SWI as a sensitive marker of microvascular integrity that is not dependent on a hypertensive aetiology, and argues for its inclusion in the imaging work-up of patients with unexplained neurological symptoms regardless of blood-pressure status. Symptom-imaging correlation in this cohort further underscored that common presenting complaints such as headache and seizures are radiologically non-specific, whereas focal symptoms such as weakness and mouth deviation correlated more consistently with infarction, and post-traumatic presentations correlated with haemorrhage or normal imaging. Taken together, these findings support incorporating SWI into routine brain MRI protocols for patients with vascular risk factors or unexplained neurological symptoms, as it can reveal microvascular haemorrhagic change that would otherwise be missed on conventional sequences. Early identification of such change may inform decisions around antithrombotic therapy and blood-pressure control, and may help identify patients at higher risk of future haemorrhagic or ischaemic events.

4.1 Limitations

This study has several limitations. The sample size (n = 100) was modest and limits generalisability and subgroup comparison between hypertensive and normotensive patients. The cross-sectional, observational design precludes causal inference, and longitudinal follow-up would be needed to characterise the evolution of microbleeds over time. Comorbidities other than hypertension (diabetes, smoking, hyperlipidaemia, anticoagulant use) were not systematically stratified, and microbleeds were assessed qualitatively (presence/absence of blooming by region) rather than quantified using a standardised scale such as MARS, limiting comparability with other studies. Clinical assessment relied on presenting symptoms rather than validated neurological scoring instruments, and imaging findings were not linked to treatment outcomes or longer-term prognosis.

CONCLUSION

Susceptibility-weighted imaging meaningfully extends the diagnostic yield of brain MRI by revealing cerebral microbleeds and other microvascular abnormalities that are frequently occult on conventional sequences. In this cohort, chronic ischaemic and microvascular change was common among middle-aged and elderly patients irrespective of hypertensive status, while the clinical presentations most often associated with these changes—weakness and headache—showed variable radiological correlation. These findings support the routine use of SWI in patients with unexplained neurological symptoms or vascular risk factors, while highlighting the need for larger, longitudinal studies using standardised microbleed-rating systems to clarify the prognostic significance of SWI findings and to guide integration of clinical, imaging and laboratory data in the management of cerebrovascular and neurodegenerative disease.

Declarations

Ethical approval: Obtained from the Institutional Ethics Committee prior to patient enrolment [committee name/approval number to be inserted by the author].
Informed consent: Written informed consent was obtained from all participants [confirm and insert details].
Conflict of interest: The authors declare no conflict of interest.
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Author contributions: Y.C.N. and C.K. contributed to study conception, data acquisition, analysis and manuscript preparation.

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