

## Research Article

# MAGNETIC RESONANCE IMAGING EVALUATION OF CEREBROVASCULAR ACCIDENTS

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**Abstract: Introduction:** Stroke can be broadly categorized into ischemic and hemorrhagic types, each with unique imaging characteristics. Ischemic stroke accounts for approximately 80–85% of all cases and occurs due to an obstruction in cerebral blood flow, commonly caused by thrombosis, embolism, or small-vessel disease. **Material and methods:** All collected data were entered into Microsoft Excel and analyzed using appropriate statistical methods. Descriptive statistics were used to summarize the data, and inferential tests (such as Chi-square test) were applied where required. A p-value < 0.05 was considered statistically significant. **Results:** The vascular territory distribution is illustrated in Table 4. The middle cerebral artery territory was the most frequently involved region, followed by multiple territory and vertebrobasilar involvement, indicating predominance of anterior circulation strokes. **Conclusion** The study also revealed a strong association between stroke and comorbid conditions such as diabetes mellitus, hypertension, and cardiovascular diseases.

**Keywords:** Cerebrovascular accident (CVA) Stroke Ischemic stroke Hemorrhagic stroke Brain infarction Intracerebral hemorrhage

## INTRODUCTION

The evaluation and management of cerebrovascular disorders, particularly stroke, have experienced a remarkable transformation over recent decades due to significant advances in neuroimaging. Traditionally, the diagnosis of stroke relied heavily on clinical presentation and basic imaging modalities such as plain radiographs and conventional angiography. Although these early tools provided a degree of anatomical information, they were limited in sensitivity and specificity, particularly for detecting early ischemic changes. As a result, early therapeutic interventions were often delayed, leading to irreversible brain injury and poor outcomes.<sup>1</sup>

The rapid progression of imaging technology has revolutionised how clinicians diagnose, classify, and treat stroke. Neuroimaging has evolved from a tool for confirming the presence of stroke to a critical component in therapeutic decision-making, particularly for reperfusion therapies such as intravenous thrombolysis and mechanical thrombectomy.<sup>2</sup>

Among these imaging modalities, Magnetic Resonance Imaging (MRI) has become a cornerstone technology

due to its ability to offer high-resolution anatomical detail alongside advanced functional and metabolic assessment. Unlike computed tomography (CT), MRI does not expose patients to ionising radiation and provides superior soft-tissue contrast, making it especially valuable in differentiating between ischemic and hemorrhagic lesions.<sup>3</sup> When placed in a strong magnetic field and subjected to radiofrequency pulses, these protons absorb and emit energy, which is then translated into detailed cross-sectional images.<sup>4</sup> Stroke can be broadly categorized into ischemic and hemorrhagic types, each with unique imaging characteristics. Ischemic stroke accounts for approximately 80–85% of all cases and occurs due to an obstruction in cerebral blood flow, commonly caused by thrombosis, embolism, or small-vessel disease.

Early morphological delineation of stroke lesions allows clinicians to determine eligibility for reperfusion therapies such as intravenous thrombolysis, which has a therapeutic window of 4.5 hours, and mechanical thrombectomy, which can be extended up to 24 hours in select cases.<sup>5</sup>

Despite significant advances, gaps remain in integrating MRI techniques for comprehensive stroke assessment.

While diffusion and perfusion imaging are widely employed, their application in vascular territory mapping and metabolic profiling remains underutilised. Moreover, there is limited evidence correlating these advanced imaging features with long-term clinical outcomes in diverse patient populations.

This study aims to address these gaps by evaluating the role of MRI in delineating vascular territories and assessing metabolic alterations in ischemic stroke using MR spectroscopy. The objectives include correlating imaging findings with clinical presentations and functional outcomes, assessing the diagnostic accuracy of MRI-based territory mapping, and exploring the prognostic value of spectroscopic markers. Ultimately, this research seeks to enhance diagnostic accuracy, guide individualised treatment strategies, and contribute to the broader understanding of cerebrovascular imaging.

## MATERIALS AND METHODS

Study Design: A **prospective observational hospital-based study**.

### Inclusion Criteria

- Patients of **all age groups and both sexes**
- Patients **clinically suspected of stroke**
- Patients **referred for MRI evaluation of the brain**
- Patients who **provided informed consent**

### Exclusion Criteria

- Patients who **did not provide consent**

## RESULTS

The age and gender distribution of the study participants is depicted in Table 1. The majority of patients belonged to the elderly age group, with a statistically significant male predominance among stroke cases.

The distribution of presenting complaints is shown in Table 2. Headache, vertigo, hemiplegia, and visual disturbances were the most common presenting symptoms, and the variation in clinical presentation was found to be statistically significant.

MRI findings among study participants are presented in Table 3. T2WI and FLAIR sequences detected abnormalities in all patients, while diffusion restriction was identified in the majority of cases. SWI sequences additionally demonstrated hemorrhagic changes and microbleeds in a considerable proportion of patients.

The vascular territory distribution is illustrated in Table 4. The middle cerebral artery territory was the most frequently involved region, followed by multiple territory and vertebrobasilar involvement, indicating predominance of anterior circulation strokes.

Site-wise distribution within the ACA territory is shown in Table 5, where left- and right-sided involvements were equally observed. Table 6 demonstrates that left-sided MCA infarcts were more common than right-sided lesions. Brainstem involvement (Table 7) was predominantly left-sided, while multiple territory infarcts (Table 8) were mainly bilateral in distribution.

Posterior circulation involvement is presented in Tables 9–11. PCA territory infarcts were more common on the right side, vertebrobasilar infarcts predominantly showed bilateral involvement, and watershed infarcts demonstrated nearly equal bilateral and left-sided distribution.

- Patients with **intracranial tumors**
- Patients with **metallic implants, pacemakers, aneurysm clips, or prosthetic valves**
- **Claustrophobic patients**

### Ethical Considerations

Approval was obtained from the **Institutional Ethical Committee** prior to the commencement of the study. Written **informed consent** was obtained from all participants. Confidentiality of patient data was strictly maintained.

### Data Collection Procedure

#### MRI Technique

MRI was performed using a **1.5 Tesla scanner**. The imaging protocol included:

- T1-weighted imaging (T1WI)
- T2-weighted imaging (T2WI)
- Fluid-attenuated inversion recovery (FLAIR)
- Diffusion-weighted imaging (DWI)
- Apparent diffusion coefficient (ADC) mapping
- Gradient echo (GRE) / Susceptibility-weighted imaging (SWI)

### Statistical Analysis

All collected data were entered into **Microsoft Excel** and analyzed using appropriate statistical methods. Descriptive statistics were used to summarize the data, and inferential tests (such as Chi-square test) were applied where required. A **p-value < 0.05** was considered statistically significant.

The distribution of stroke subtypes is shown in Table 12, where ischemic stroke constituted the majority of cases, followed by hemorrhagic stroke and a small proportion of venous infarcts. Diagnostic categorization in Table 13 revealed acute infarcts as the most common diagnosis, followed by hemorrhagic infarcts, subacute infarcts, embolic infarcts, and posterior circulation infarcts.

Table 14 depicts infarct location according to infarct age. Acute infarcts commonly involved both cortical and deep structures, whereas subacute infarcts demonstrated a greater predominance of deep territorial involvement.

**Table 1: Age and gender Distribution of Study Participants**

Age groups	Frequency	Chi square value	p value
18 to 30 years	5	64.3	<0.01**
31 to 45 years	14		
46 to 60 years	22		
61 to 75 years	50		
>75 years	9		
Male	73	21.6	<0.01**
Female	27		

**Table 2: Distribution of Chief Complaints Among Study Participants**

Chief complaints	Present	Absent	Chi square value	p value
Headache	48	52	75.7	<0.01**
Hemiplegia	34	66		
Vertigo	40	60		
Vomiting	22	78		
Visual Disturbances	35	65		
Gait Disturbances	27	73		
Facial Palsy	22	78		

**Table 3: MRI Findings Among Study Participants**

Investigations: MRI	Frequency	Percent
T2WI Lesion	100	100
D.W. I. Restriction	95	95
S.W.I. hemorrhage/microbleeds	53	53
FLAIR	100	100

**Table 4: Distribution of Vascular Territory Involvement Among Study Participants**

Vascular Territory	Frequency	Percent
CVT	2	2
ACA	5	5
Brainstem	6	6
PCA	10	10
Vertebrobasilar	11	11
Watershed	10	10
Multiple	14	12
MCA	42	43
Total	100	100

**Table 5: Distribution of Site of Involvement in ACA/MCA Territory**

ACA/ MCA	Frequency	Percent
Site of involvement		
Left	2	40
Middle	1	20
Right	2	40
Total	5	100

**Table 6: Site-wise Distribution of MCA Territory Involvement**

<b>MCA</b>		
Site of involvement	Frequency	Percent
Left	28	66.67
Right	14	33.33
Total	42	100

**Table 7: Site-wise Distribution of Brainstem Involvement**

<b>Brainstem</b>		
Site of involvement	Frequency	Percent
Left	3	50
Middle	2	33.33
Right	1	16.67
Total	6	100

**Table 8: Site-wise Distribution of Multiple Territory Involvement**

<b>Multiple</b>		
Site of involvement	Frequency	Percent
Bilateral	7	70
Right	3	30
Total	10	100

**Table 9: Site-wise Distribution of PCA Territory Involvement**

<b>PCA</b>		
Site of involvement	Frequency	Percent
Left	2	20
Right	5	50
Bilateral	3	30
Total	10	100

**Table 10: Site-wise Distribution of Vertebrobasilar Territory Involvement**

<b>Vertebrobasilar</b>		
Site of involvement	Frequency	Percent
Left	2	20
Right	1	10
Bilateral	7	70
Total	10	100

**Table 11: Site-wise Distribution of Watershed Territory Involvement**

<b>Watershed</b>		
Site of involvement	Frequency	Percent
Left	4	40
Right	2	20
Bilateral	4	40
Total	10	100

**Table 12: Distribution of Stroke Types Among Study Participants**

Stroke Type	Frequency	Percent
Hemorrhagic	23	23
Ischemic	75	75
Venous infarct	2	2
Total	100	100

**Table 13: Distribution of Diagnosis Among Study Participants**

Diagnosis	Frequency	Percent
Acute Infarct	35	35
Haemorrhagic infarct	12	12
Subacute infarct	10	10
Embolic infarcts	9	9
Brainstem infarcts	8	8
Acute watershed infarcts	7	7
Posterior circulation infarct	6	6
Large MCA infarct	4	4
Hypoxic Injury	3	3
Post-op infarcts	2	2
CVT with venous infarct	1	1
Massive infarct	1	1
TB vasculitis infarcts	1	1
Thalamic Bleed	1	1
Total	100	100

**Table 14: Distribution of Infarct Location According to Age of Infarct**

Age of Infarct	Deep vs Cortical	Frequency	Percent
Acute (n = 84)	Cortical + Deep	33	39.29
	Cortical	22	26.19
	Deep	29	34.52
Subacute (n = 16)	Cortical + Deep	3	18.75
	Cortical	4	25.00
	Deep	7	43.75

**CASE I**

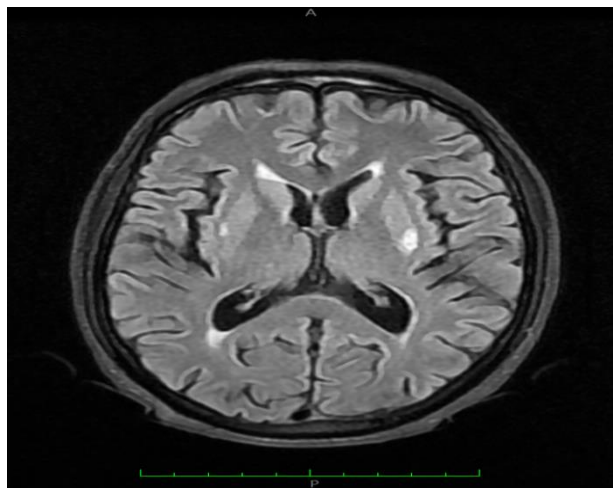
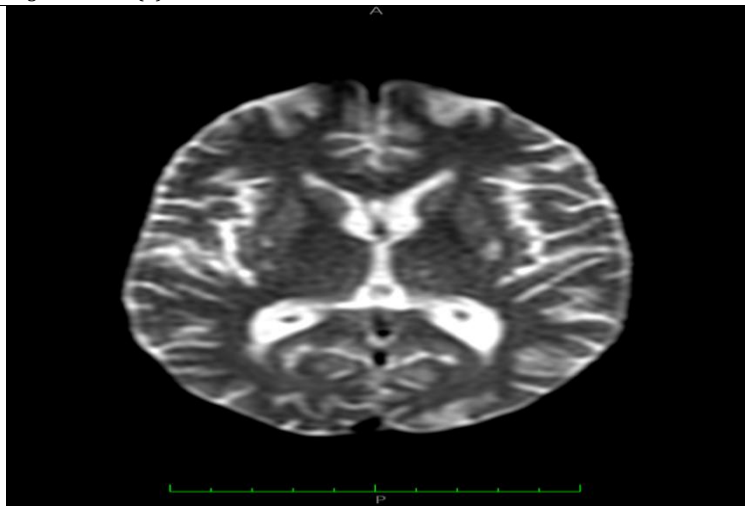
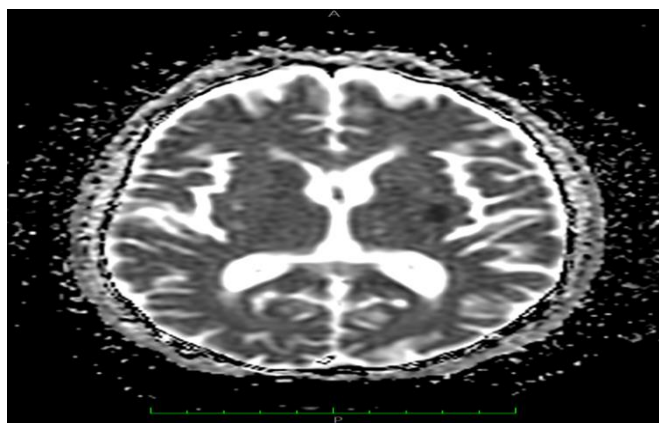


Image 1: An ill-defined hyperintense lesion on T2-weighted (T2W) and fluid-attenuated inversion recovery (FLAIR) sequences involving the posterior aspect of the left lentiform nucleus.

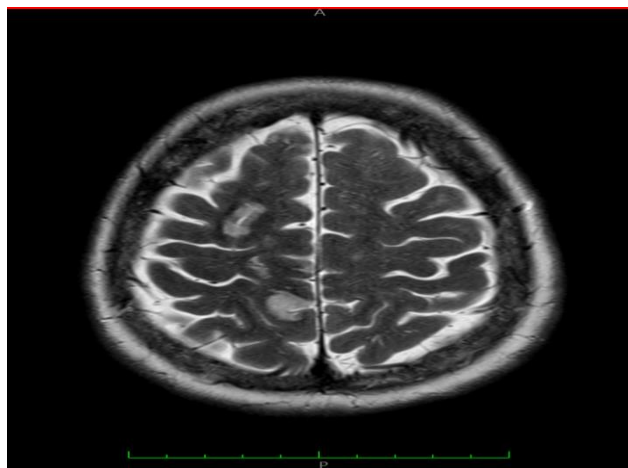


**Image 2:** Focal diffusion restriction is noted in the left lentiform nucleus on diffusion-weighted imaging (DWI), consistent with acute ischemia.



**Image 3:** Corresponding diffusion restriction is noted in the posterior aspect of the left lentiform nucleus, appearing as low signal intensity on the apparent diffusion coefficient (ADC) map.

## CASE II



**Image 1:** Multiple T2-weighted (T2W) and FLAIR hyperintense areas are seen in the right cerebral hemisphere, involving the high frontal region, frontal lobe, and centrum semiovale, suggestive of ischemic changes.

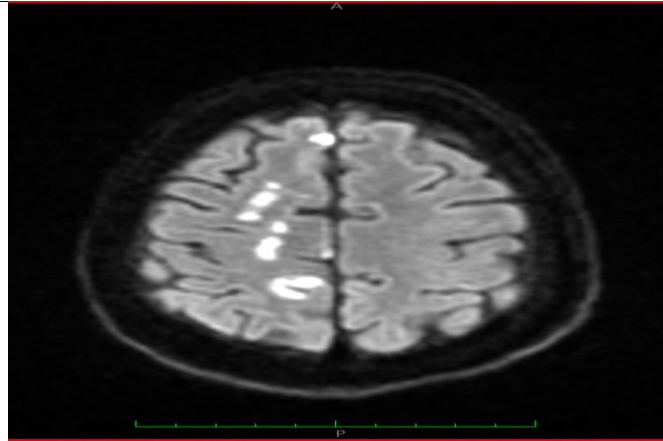


Image 2: Areas of diffusion restriction are noted in the right high frontal region, involving the frontal lobe and centrum semiovale, consistent with acute ischemic changes.

### CASE III

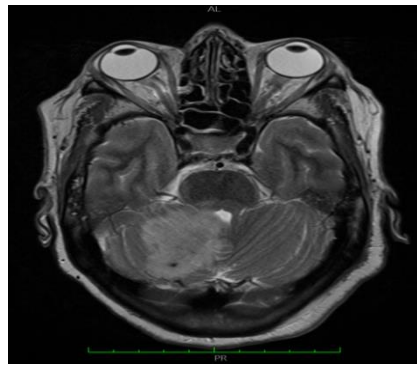


Image 1: Heterogeneous hyperintensity on T2-weighted (T2W) and FLAIR sequences involving the right hemi-pons, right superior cerebellar parenchyma, and cerebellar peduncle.

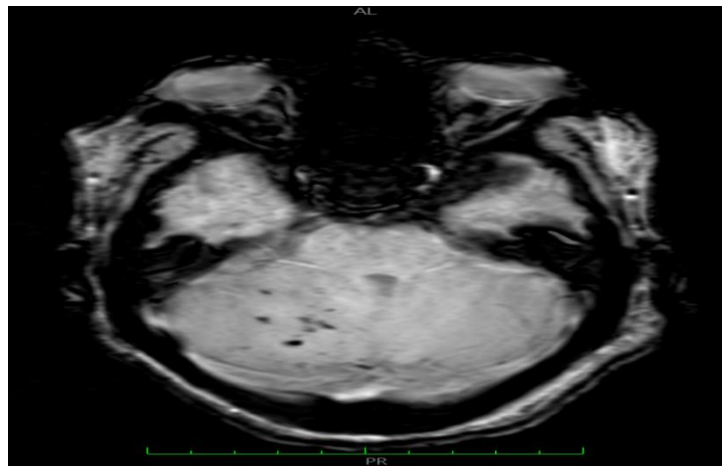
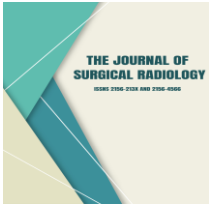


Image 2: Few foci of SWI susceptibility seen in right cerebellum - hemorrhagic foci.



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## DISCUSSION

The present study was undertaken to evaluate the role of MRI in the assessment of cerebrovascular accidents, with emphasis on vascular territory involvement and characterization of ischemic and hemorrhagic lesions. MRI has emerged as an indispensable imaging modality in stroke evaluation due to its superior soft tissue contrast, high sensitivity in early infarct detection, and ability to identify vascular and hemorrhagic changes. The findings of the present study were analyzed and compared with previous national and international studies to assess similarities and variations in demographic profile, clinical presentation, MRI findings, vascular territory distribution, and stroke subtypes.

This demographic pattern underscores the increased susceptibility to cerebrovascular events in older populations. This finding is consistent with broader epidemiological trends. For instance, a study by Kaur et al. (2020) in Southwest Rajasthan, India, also identified a significant prevalence of stroke in older age groups with mean age of  $60.46 \pm 14.84$  years.<sup>6</sup> Supporting this, Sridharan et al. (2009, India) in the Trivandrum Stroke Registry reported a median stroke age of 67 years with a very low proportion (3.8%) of patients below 40 years,<sup>7</sup> reinforcing the strong age-dependent rise in stroke incidence with a predominant burden in elderly populations. Ojha et al. (2019, India) similarly demonstrated that nearly half of stroke cases clustered in the 46–65 year age group with progressively increasing incidence beyond 65 years,<sup>8</sup> further supporting the observed shift toward middle-to-older age predominance. Collectively, these studies align with the present findings by confirming age as a dominant non-modifiable risk factor for cerebrovascular accidents, while minor differences in age distribution patterns may be attributed to variations in study design (community-based vs hospital-based), population demographics, healthcare access, and imaging-based case selection, which often results in greater representation of elderly patients in tertiary care MRI cohorts.

The Ram et al. study found 72.3% male,<sup>9</sup> and the JCCP series similarly observed 71% male patients (male:female  $\approx 2.4:1$ ).<sup>10</sup> Supporting this pattern, Baskar and Revathy (2013) in a descriptive cross-sectional hospital-based study also reported male predominance (58% males vs 42% females) among acute stroke patients, indicating a consistent though less pronounced gender gap in cerebrovascular disease.<sup>11</sup>

An analysis of chief complaints in the current cohort indicated that headache (48%), visual disturbances

(35%), hemiplegia (34%), and vertigo (40%) were among the most frequently reported symptoms, all showing high statistical significance ( $p < 0.01^{**}$ ). These findings reflect the diverse clinical presentations of stroke, depending on the affected brain region. Handanović et al. (2021) highlighted that stroke diagnosis requires rapid and efficient assessment to eliminate other potential causes of neurological deficits, implying the varied symptomatology commonly observed in stroke patients.<sup>12</sup> Jain et al. (2019, India), in a prospective hospital-based observational study of acute stroke patients, also reported headache as the most common neurological symptom (33.33%), followed by convulsions and TIA, supporting the prominence of headache as an early clinical feature in acute cerebrovascular events.<sup>13</sup>

The MRI findings from the current study demonstrated 100% positivity for T2WI and FLAIR hyperintensities, 95% for DWI restriction, and 53% for SWI hemorrhage/microbleeds. The universal presence of T2WI and FLAIR hyperintensities in all patients is scientifically sound, as T2 hyperintensity reflects increased tissue water content due to cytotoxic or vasogenic edema and is commonly seen once infarction is established.<sup>14</sup> This temporal behavior is supported by Thomalla et al. (2011), who demonstrated that FLAIR hyperintensity is present in only about 50% of acute stroke patients imaged within 12 hours, increasing with time from symptom onset, thereby acting as a marker of stroke age.<sup>15</sup> Similarly, Petkova et al. (2010) reported that FLAIR changes typically emerge after approximately 6 hours and are useful in estimating stroke duration,<sup>16</sup> while Cho et al. (2008) highlighted its relevance in established infarcts and post-thrombolysis outcomes.<sup>17</sup>

The 95% DWI positivity in the present study aligns with its established role as the most sensitive sequence for acute ischemia. Thomalla et al. (2011) similarly reported DWI positivity in approximately 95% of acute stroke cases, reinforcing its reliability in early lesion detection even when FLAIR changes are absent.<sup>15</sup> Knight et al. (2019), in a translational study involving both animal MCA occlusion models and a human acute ischemic cohort, demonstrated that diffusion restriction reliably defines ischemic core regions and remains consistently detectable across time, while also showing time-dependent evolution of associated T2 signal changes.<sup>18</sup> Their findings support the current observation that diffusion-weighted imaging serves as a robust marker of acute infarction, while T2-weighted changes reflect evolving tissue injury. However, their study focused on quantitative voxel-based temporal changes in T2 relaxation, whereas the present study evaluates

categorical MRI findings across sequences, reflecting lesion presence rather than kinetic evolution.

The distribution of vascular territory involvement showed that the middle cerebral artery (MCA) territory was the most frequently affected (43%), followed by multiple territories (12%) and vertebrobasilar territory (11%). This predominance of MCA involvement is consistent with its well-established anatomical and hemodynamic vulnerability, as it is the largest intracranial artery and a direct continuation of the internal carotid system, making it a frequent site for embolic occlusion.<sup>19</sup> Prior literature also consistently reports MCA as the most commonly involved vascular territory in ischemic stroke, with a majority of infarcts occurring within its distribution. Imaging-based studies further support the role of MRI, particularly diffusion-weighted imaging, in accurately delineating vascular territory involvement and characterizing both large vessel and small vessel infarcts.<sup>12,20</sup> The observed involvement of multiple territories and vertebrobasilar circulation suggests a subset of patients with embolic or more extensive cerebrovascular pathology, which is often associated with complex clinical presentations and potentially poorer outcomes. Overall, the vascular distribution pattern in the present study closely mirrors established stroke epidemiology, reinforcing the MCA territory as the most common site of infarction while also highlighting the presence of multi-territorial and posterior circulation involvement reflecting diverse stroke mechanisms.

The left hemisphere dominance in MCA strokes in this study might reflect a higher prevalence of embolism originating from the left carotid artery or other systemic sources with preferential flow to the left MCA, though further research is required to ascertain the precise etiology in this cohort. The observation is further supported by Prerana et al. (2024), who in a cross-sectional MRI-based study of stroke patients reported a similar left hemispheric predominance (50%) compared to right-sided involvement (40%), with MCA being the most frequently affected arterial territory (66%).<sup>21</sup> Overall, these findings collectively reinforce the consistent predominance of MCA territory strokes and a tendency toward left hemispheric involvement across MRI-based stroke evaluation studies.

Ischemic strokes constituted 75%, hemorrhagic 23%, and venous infarcts 2% of our cohort. This distribution aligns with national averages: ischemic strokes usually account for ~70–80% of cases in India.<sup>22</sup> Our 75% ischemic rate falls in this range. The hemorrhage proportion (23%) is somewhat higher than some Indian averages (typically ~20–30%) but similar to many hospital-based reports.<sup>22</sup> Jones et al. (2021) in a systematic review of population-based stroke studies also demonstrated a consistent predominance of ischemic stroke (approximately 65%–84%), with hemorrhagic strokes ranging from 11%–35% and venous

strokes remaining rare at around 1%–2%,<sup>23</sup> supporting the overall pattern observed in the present study. Similarly, Leena et al. (2025), in a large retrospective analysis of 524 stroke patients from a tertiary care centre, reported ischemic stroke predominance (84.9%), followed by hemorrhagic stroke (15.1%), with very low venous infarct occurrence, reflecting a comparable hospital-based distribution pattern influenced by similar vascular risk profiles.<sup>24</sup> Rathod et al. (2025), in an MRI-based cross-sectional study of stroke patients, also observed ischemic stroke as the most common subtype (70%), followed by intracerebral hemorrhage (20%) and venous thrombosis (10%), further reinforcing the diagnostic strength of MRI in distinguishing stroke subtypes.<sup>25</sup> By comparison, Western populations report a higher ischemic proportion of around 85%, indicating that South Asian cohorts, including the present study, show a relatively greater hemorrhagic contribution. The low venous infarct rate (2%) is consistent with its known rarity in most stroke series. Overall, the present findings are in strong agreement with existing Indian epidemiological and imaging-based literature, reinforcing the predominance of ischemic stroke while highlighting variability in hemorrhagic proportions due to differences in study design, imaging utilization, and hospital-based selection bias.

The distribution of infarct location according to the age of infarct shows distinct spatiotemporal patterns in ischemic stroke evolution. In the acute phase (n=84), infarcts were most commonly deep (34.52%) or combined cortical–deep (39.29%), with purely cortical lesions in 26.19%, reflecting involvement of both perforator territories and large-vessel cortical branches. A similar pattern was reported by Moheem et al. (2022), where MRI-based evaluation showed a predominance of deep gray matter infarcts, particularly involving basal ganglia structures supplied by end-arteries, consistent with acute occlusive vascular events.<sup>26</sup>

In contrast, the subacute phase (n=16) demonstrated a shift toward predominantly deep infarcts (43.75%), followed by cortical (25%) and combined lesions (18.75%). This likely reflects persistence and clearer delineation of small-vessel disease-related infarcts, while larger combined lesions may present earlier or be associated with worse outcomes. Similar observations were noted by Manjunath and Jeevika (2024), who reported frequent deep infarcts in basal ganglia and internal capsule regions, strongly associated with hypertension-related small-vessel disease.<sup>27</sup>

Overall, the higher proportion of combined cortical–deep infarcts in the acute phase likely reflects large-artery or cardioembolic strokes, whereas the subacute predominance of isolated deep infarcts suggests a stronger contribution of chronic small-vessel pathology. This interpretation aligns with Ramamurthy et al. (2023), who highlighted small-vessel disease as a major cause of deep territorial infarcts in regional stroke populations.<sup>28</sup>

Collectively, these studies support a temporal shift in infarct patterns and reinforce the value of MRI-based stratification of stroke according to infarct age for improved etiological interpretation.

## CONCLUSION

The present study highlights that cerebrovascular accidents predominantly affect elderly individuals, with a significant male preponderance. Ischemic stroke emerged as the most common subtype, with the middle cerebral artery being the most frequently involved vascular territory. MRI, particularly diffusion-weighted imaging, T2-weighted imaging, and FLAIR sequences, demonstrated high sensitivity in detecting both acute and established infarcts, while SWI contributed to the identification of hemorrhagic components. The study also revealed a strong association between stroke and comorbid conditions such as diabetes mellitus, hypertension, and cardiovascular diseases. Clinical presentation was variable, with headache and focal neurological deficits being the most common symptoms. Overall, MRI proved to be an indispensable tool in early diagnosis, vascular territory delineation, and characterization of stroke, thereby aiding in accurate diagnosis and guiding appropriate management.

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