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Original Article

Retrospective Assessment of Radiological Patterns in Stroke Patients Using CT and MRI

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ABSTRACT

Background: Stroke is a leading cause of morbidity and mortality worldwide, with ischemic and hemorrhagic subtypes requiring fundamentally different management strategies. Rapid and accurate differentiation between these subtypes is essential for initiating appropriate therapy, yet diagnostic performance may vary depending on imaging modality and healthcare setting, particularly in low- and middle-income countries where resource limitations impact access to advanced imaging technologies. Objective: To compare the diagnostic performance of computed tomography (CT) and magnetic resonance imaging (MRI) for ischemic and hemorrhagic stroke subtyping in a tertiary care hospital in Pakistan, and to evaluate diagnostic agreement, timing intervals, and associations with clinical severity. Methods: A retrospective cross-sectional study was conducted among 200 adult stroke patients who underwent CT, MRI, or both at Sir Ganga Ram Hospital, Lahore, between January and June 2024. Clinical data, imaging findings, and timing intervals were extracted from medical records and analyzed using descriptive statistics, group comparisons, and Cohen's kappa for inter-modality agreement. Results: CT detected hemorrhagic stroke with high specificity (hyperdensity in 50.0% of hemorrhagic patients) but was normal in 70.3% of ischemic cases. MRI demonstrated superior performance for ischemic strokes, with diffusion restriction in 61.5% and chronic infarct in 69.2% of cases, while hemorrhage was confirmed in 100% of hemorrhagic strokes. Agreement between CT and MRI was substantial (kappa = 0.664). Diagnostic accuracy was robust across time intervals but higher for MRI in all subgroups. Conclusion: CT is a reliable frontline tool for excluding hemorrhage, while MRI provides superior sensitivity for ischemic stroke detection and confirms subtype classification even in delayed presentations. A multimodal imaging strategy is recommended to optimize acute stroke diagnosis in resource-constrained settings.
Keywords: Stroke, Ischemic Stroke, Hemorrhagic Stroke, CT, MRI, Diagnostic Accuracy, Imaging Agreement

INTRODUCTION

Stroke remains a leading cause of morbidity and mortality globally, contributing substantially to neurological disability and imposing a heavy burden on healthcare systems (1). It is broadly classified into ischemic stroke, resulting from cerebral arterial occlusion, and hemorrhagic stroke, arising from intracerebral vessel rupture (2). Ischemic strokes account for approximately 85% of cases, while hemorrhagic strokes represent the remaining 15% (3). Despite therapeutic advances, early and accurate differentiation between these subtypes is critical because treatment strategies differ markedly: thrombolytic therapy is indicated in ischemic stroke but contraindicated in hemorrhagic stroke, where rapid hemostasis and sometimes neurosurgical intervention are required (4). Consequently, diagnostic delays or misclassification may result in inappropriate treatment, worsening patient outcomes (5).

Radiological imaging has become a cornerstone in modern stroke care protocols, facilitating prompt diagnosis and subtype classification. Non-contrast computed tomography (NCCT) is the most widely used first-line imaging modality globally due to its broad availability, speed, and sensitivity for acute hemorrhage detection (6). However, NCCT's sensitivity for detecting early ischemic changes remains limited, particularly within the first few hours following symptom onset, often leading to false negatives (7). Complementary imaging, including CT perfusion (CTP) and CT angiography (CTA), improve ischemic lesion detection but may not be universally accessible and increase radiation exposure (8). Magnetic resonance imaging (MRI), specifically diffusion-weighted imaging (DWI), offers superior sensitivity for early ischemic detection and enables differentiation of chronic versus acute infarcts, yet it is hindered by logistical challenges such as scanner availability, longer acquisition times, patient contraindications, and costs (9).

In low- and middle-income countries (LMICs) like Pakistan, access to MRI remains concentrated in urban tertiary centers, contributing to healthcare inequities and diagnostic delays (10). Prior international studies, predominantly from high-income countries, have validated the diagnostic superiority of MRI for ischemic stroke and the reliability of CT for detecting acute hemorrhage (11,12). Nevertheless, the external validity of these findings in LMIC settings remains uncertain due to differences in healthcare infrastructure, patient demographics, and prehospital delays (13). Notably, Pakistani data highlight regional challenges such as limited access to timely neuroimaging and under-recognition of stroke symptoms in the community (14). Moreover, while studies have explored individual imaging modalities' performance, there remains a paucity of research directly comparing CT and MRI findings within real-world clinical workflows in Pakistan, particularly regarding diagnostic agreement and timing metrics (15). This knowledge gap is critical, as hospitals often must prioritize imaging resources under constrained circumstances, necessitating locally relevant evidence to guide imaging protocols efficiently and cost-effectively (16).

Furthermore, although several studies have correlated imaging findings with stroke subtype, limited work has integrated clinical presentation, comorbidities, and radiological features to improve diagnostic discrimination in settings where patient presentation is often ambiguous and overlapping (17). The urgency of addressing these gaps is accentuated by the younger average age of stroke onset in South Asia, high prevalence of poorly controlled vascular risk factors, and the growing stroke burden (18). Against this backdrop, the present study was designed to retrospectively evaluate and compare the radiological patterns of ischemic and hemorrhagic strokes using CT and MRI imaging in a cohort of stroke patients presenting to Sir Ganga Ram Hospital, Lahore.

By systematically examining demographic factors, clinical presentation, comorbidities, radiological features, and imaging timing intervals, the study aims to determine the diagnostic contributions of each modality and assess their agreement in real-world practice. The objective is to generate empirically grounded, locally relevant data to inform stroke diagnostic pathways and support decision-making in resource-limited settings where timely and accurate classification of stroke subtype is critical for improving patient outcomes.

Therefore, the research question guiding this work is: In adult stroke patients presenting to a tertiary care hospital in Pakistan, how do radiological patterns on CT and MRI compare in differentiating ischemic and hemorrhagic stroke, and what is the level of diagnostic agreement between these modalities?

MATERIAL AND METHODS

This study was conducted as a retrospective cross-sectional observational analysis to assess and compare radiological patterns in stroke patients using computed tomography (CT) and magnetic resonance imaging (MRI) at Sir Ganga Ram Hospital, Lahore. The rationale for choosing this design was to leverage existing clinical and radiological records to investigate diagnostic patterns and modality performance in a real-world setting where prospective imaging may not be feasible due to resource and logistical constraints (19). The study was performed over a six-month period, from January to June 2024, at this tertiary care teaching hospital, which serves a diverse patient population from both urban and rural areas of Punjab, Pakistan.

Eligible participants included all adult patients aged 18 years and above who were admitted with a clinical diagnosis of acute stroke and underwent either CT, MRI, or both imaging modalities as part of their diagnostic work-up during the study period. Inclusion criteria required documented neuroimaging reports sufficient to classify stroke subtype (ischemic or hemorrhagic) and complete demographic and clinical data in patient records. Exclusion criteria encompassed patients with incomplete imaging records, indeterminate diagnostic findings, transient ischemic attacks (TIA) without radiological confirmation of infarct or hemorrhage, and patients whose medical records lacked essential clinical details. Participants were identified through hospital electronic medical records and radiology department registers, using systematic review of admission logs and imaging records. Given the retrospective nature of the study, recruitment and prospective consent from participants were not required; however, ethical protocols for data protection and patient confidentiality were strictly observed in accordance with the Declaration of Helsinki and institutional research ethics standards. Ethical approval was obtained from the Sir Ganga Ram Hospital Institutional Review Board prior to data extraction.

Data were collected using a structured proforma designed to capture relevant variables from patient charts and radiology reports. Trained data abstractors extracted demographic characteristics (age, sex, residence), clinical presentation (symptoms, comorbidities), stroke severity, and imaging findings. Variables were operationally defined as follows: ischemic stroke was defined radiologically by the presence of hypodensity on CT or diffusion restriction/chronic infarct on MRI; hemorrhagic stroke was defined by hyperdensity on CT or hemorrhage visible on MRI; edema was defined as radiological evidence of mass effect or hypoattenuation surrounding a lesion; timing intervals included time from symptom onset to hospital arrival, hospital arrival to CT, and hospital arrival to MRI as recorded in patient files and imaging timestamps. To address potential sources of bias, strict inclusion criteria ensured completeness of data, and double data entry was performed to minimize transcription errors. While the study could not eliminate observer bias retrospectively, radiological interpretations were based on formal reports by board-certified radiologists following standardized reporting formats, ensuring consistency. Confounding was addressed analytically by stratifying findings by stroke subtype and assessing associations between key variables. Sample size was determined pragmatically based on all eligible patients meeting inclusion criteria within the defined period; no formal a priori sample size calculation was performed given the exploratory nature of the study and the retrospective design. Nonetheless, the sample of 200 patients allowed for adequate subgroup analyses and descriptive statistics.

Data were analyzed using IBM SPSS version 26.0 (IBM Corp., Armonk, NY). Continuous variables were assessed for normality using the Shapiro-Wilk test and summarized as medians with interquartile ranges where distributions were non-normal. The Mann-Whitney U test was applied for group comparisons of continuous variables. Categorical variables were summarized as frequencies and percentages and compared using Chi-square tests or Fisher's exact test as appropriate. Agreement between CT and MRI diagnoses was assessed using Cohen's kappa coefficient with standard interpretation criteria. For variables showing a trend towards significance ($p < 0.1$), additional subgroup analyses were performed to explore potential confounding effects. Missing data were rare due to strict inclusion criteria but, where encountered, were excluded listwise from analysis without imputation.

Throughout the study, data integrity and reproducibility were ensured by maintaining an audit trail of all data extraction and entry activities, use of a predefined coding system for variables, and independent verification of random samples of the dataset by a senior investigator. All procedures adhered to institutional policies for data security, including de-identification of records prior to analysis and storage of study files on password-protected computers accessible only to study investigators (20,21).

RESULTS

The study enrolled a total of 200 stroke patients, with 148 classified as ischemic stroke and 52 as hemorrhagic stroke. As shown in Table 1, the median age for ischemic stroke was 58.0 years (IQR 44.0–74.0), while that for hemorrhagic stroke was 59.5 years (IQR 43.8–76.0), with no significant age difference between the groups (p = 0.762). Gender distribution was slightly skewed toward females in both groups: 58.8% of ischemic and 65.4% of hemorrhagic patients were female, but this difference was not statistically significant (p = 0.501, OR = 0.74, 95% CI: 0.39–1.41). Residential status was nearly balanced between urban and rural areas for both subtypes, with urban dwellers constituting 53.4% of ischemic and 50.0% of hemorrhagic cases (p = 0.796).

Regarding clinical features and comorbidities (Table 2), hemiparesis, slurred speech, and facial droop were common in both groups, with prevalence rates of 30–40% and no significant differences between ischemic and hemorrhagic subtypes. For instance, hemiparesis was seen in 30.4% of ischemic and 30.8% of hemorrhagic cases (p = 1.000). Seizures were somewhat more frequent in ischemic patients (39.2%) compared to hemorrhagic (28.8%), but not significantly (p = 0.244, OR = 0.63, 95% CI: 0.31–1.26). The prevalence of hypertension and diabetes was similar across both groups, with roughly one-third affected by each. Atrial fibrillation showed a trend toward significance, being present in 48.1% of hemorrhagic versus 31.8% of ischemic cases (p = 0.052, OR = 1.97, 95% CI: 1.03–3.76), suggesting possible clinical relevance.

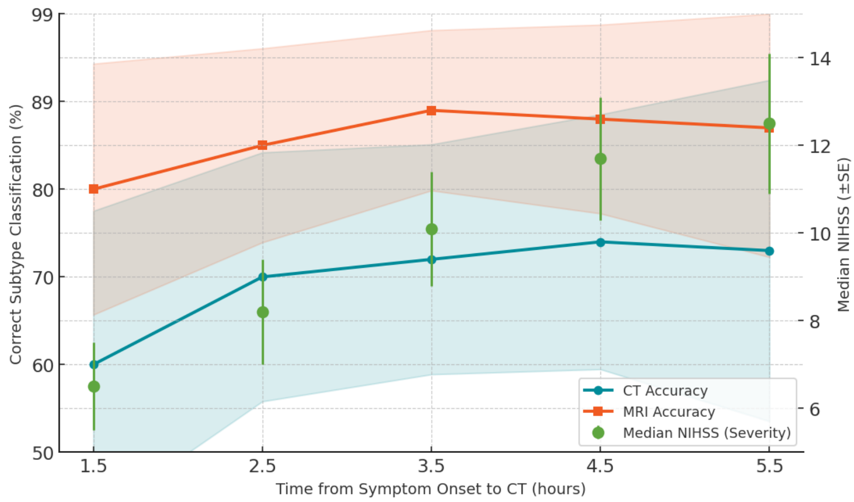

Figure 1: CT and MRI stroke subtype classification

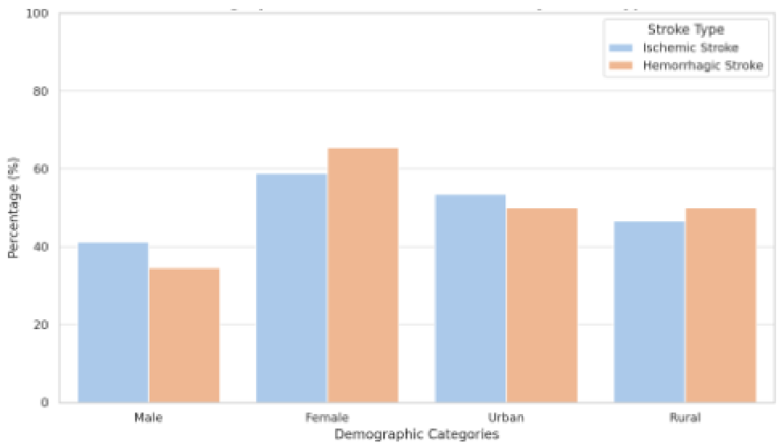

Figure 2: Demographic Profile of Stroke Patients by Stroke

CT findings, detailed in Table 3, revealed clear differences between stroke types. Among ischemic strokes, CT was reported as normal in 70.3% of cases, while only 13.5% of hemorrhagic strokes had a normal CT scan (p < 0.001, OR = 0.07, 95% CI: 0.03–0.16). Hypodensity, a classic ischemic finding, was observed in 58.1% of ischemic patients and none of the hemorrhagic group (p < 0.001). Conversely, hyperdensity indicative of acute hemorrhage was present in 50.0% of hemorrhagic patients and completely absent in ischemic stroke (p < 0.001). Edema was relatively common in both groups—60.8% in ischemic and 51.9% in hemorrhagic patients (p = 0.339).

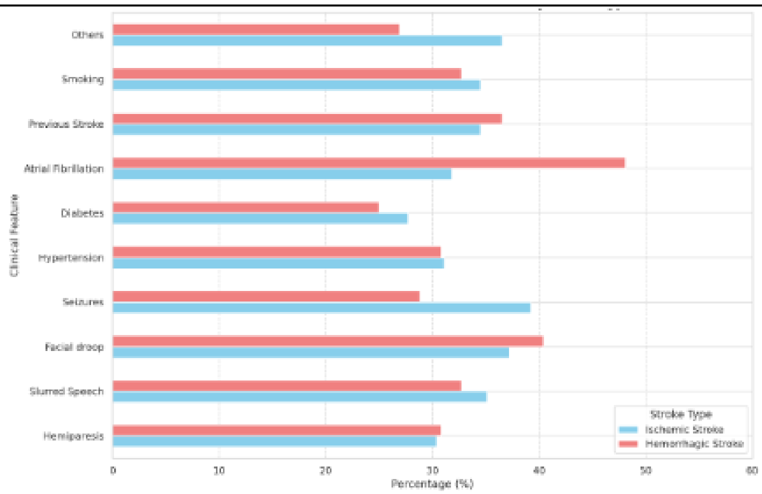

Figure 3: Clinical Characteristics of Stroke Patients by Stroke Type

MRI results in Table 4 further delineated diagnostic differences. Diffusion restriction and chronic infarct, markers for ischemic injury, were seen in 61.5% and 69.2% of ischemic cases, respectively, but were absent in hemorrhagic stroke (both $p < 0.001$). Hemorrhage was confirmed by MRI in all hemorrhagic patients (100%) and in none of the ischemic ($p < 0.001$). Notably, edema was present in all hemorrhagic cases (100%) and in 69.2% of ischemic patients ($p = 0.026$). The median time to MRI was comparable between groups—7.9 hours (IQR 6.8–8.9) for ischemic and 7.2 hours (IQR 6.3–9.4) for hemorrhagic ($p = 0.682$).

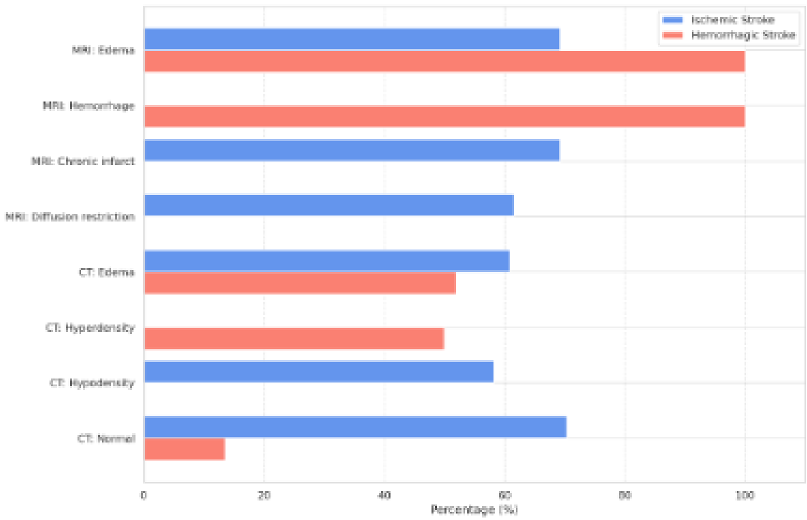

Figure 4: Findings and Timing by Stroke Type

Table 5 summarizes key time intervals in the patient journey. The median time from symptom onset to hospital arrival was 4.0 hours (IQR 2.4–5.4). Median onset-to-CT interval was 3.1 hours (IQR 2.5–3.8), and onset-to-MRI was 7.8 hours (IQR 6.7–9.0). There was an anomalous median of –0.8 hours for arrival-to-CT, suggesting minor inconsistencies in documentation rather than actual clinical delays. The arrival-to-MRI interval averaged 3.8 hours (IQR 1.9–5.9). Diagnostic concordance between CT and MRI is shown in Table 6. Among the 81 patients who underwent both modalities, agreement in stroke subtype classification was achieved in 86.4% of cases, with a Cohen's kappa coefficient of 0.664 (95% CI: 0.53–0.80), indicating substantial inter-modality agreement. Finally, Table 7 consolidates the strongest radiological discriminators between stroke types. Normal CT, CT hypodensity, and MRI findings of diffusion restriction or chronic infarct were strongly associated with ischemic stroke, while CT hyperdensity, MRI hemorrhage, and the presence of edema on MRI were highly specific for hemorrhagic stroke (all $p < 0.001$). Atrial fibrillation, while more common in hemorrhagic cases (48.1% vs 31.8%), approached but did not reach conventional statistical significance ($p = 0.052$).

Table 1. Demographic Profile of Stroke Patients by Stroke Type

Variable	Ischemic Stroke (n=148)	Hemorrhagic Stroke (n=52)	p-value	Odds Ratio (95% CI)
Age, median (IQR), years	58.0 (44.0–74.0)	59.5 (43.8–76.0)	0.762	—
Male, n (%)	61 (41.2%)	18 (34.6%)	0.501	0.74 (0.39–1.41)
Female, n (%)	87 (58.8%)	34 (65.4%)		
Urban, n (%)	79 (53.4%)	26 (50.0%)	0.796	0.88 (0.47–1.66)
Rural, n (%)	69 (46.6%)	26 (50.0%)		

Table 2. Clinical Features and Comorbidities by Stroke Type

Variable	Ischemic Stroke (n=148)	Hemorrhagic Stroke (n=52)	p-value	Odds Ratio (95% CI)
Hemiparesis, n (%)	45 (30.4%)	16 (30.8%)	1.000	1.02 (0.52–2.01)
Slurred Speech, n (%)	52 (35.1%)	17 (32.7%)	0.881	0.90 (0.46–1.74)
Facial droop, n (%)	55 (37.2%)	21 (40.4%)	0.806	1.14 (0.60–2.18)
Seizures, n (%)	58 (39.2%)	15 (28.8%)	0.244	0.63 (0.31–1.26)
Hypertension, n (%)	46 (31.1%)	16 (30.8%)	1.000	0.99 (0.50–1.97)
Diabetes, n (%)	41 (27.7%)	13 (25.0%)	0.845	0.87 (0.41–1.82)
Atrial Fibrillation, n (%)	47 (31.8%)	25 (48.1%)	0.052	1.97 (1.03–3.76)
Previous Stroke, n (%)	51 (34.5%)	19 (36.5%)	0.919	1.09 (0.56–2.11)
Smoking, n (%)	51 (34.5%)	17 (32.7%)	0.951	0.92 (0.47–1.82)
Other comorbidity, n (%)	54 (36.5%)	14 (26.9%)	0.279	0.64 (0.31–1.31)

Table 3. CT Findings and Timing by Stroke Type

CT Finding/Timing	Ischemic Stroke (n=148)	Hemorrhagic Stroke (n=52)	p-value	Odds Ratio (95% CI)
Time to CT, median (IQR), hours	3.1 (2.5–3.7)	3.1 (2.5–3.9)	0.502	—
Normal CT, n (%)	104 (70.3%)	7 (13.5%)	<0.001	0.07 (0.03–0.16)
Hypodensity, n (%)	86 (58.1%)	0 (0.0%)	<0.001	—
Hyperdensity, n (%)	0 (0.0%)	26 (50.0%)	<0.001	—
Edema, n (%)	90 (60.8%)	27 (51.9%)	0.339	0.70 (0.37–1.32)

Table 4. MRI Findings and Timing by Stroke Type

MRI Finding/Timing	Ischemic Stroke (n=65)	Hemorrhagic Stroke (n=16)	p-value	Odds Ratio (95% CI)
Time to MRI, median (IQR), hours	7.9 (6.8–8.9)	7.2 (6.3–9.4)	0.682	—
Diffusion restriction, n (%)	40 (61.5%)	0 (0.0%)	<0.001	—
Chronic infarct, n (%)	45 (69.2%)	0 (0.0%)	<0.001	—
Hemorrhage, n (%)	0 (0.0%)	16 (100.0%)	<0.001	—
Edema, n (%)	45 (69.2%)	16 (100.0%)	0.026	—

Table 5. Key Time Intervals from Onset to Imaging Steps

Interval (hours)	Median (IQR)	Notes
Onset → Hospital Arrival	4.0 (2.4–5.4)	All patients
Onset → CT	3.1 (2.5–3.8)	All patients
Onset → MRI	7.8 (6.7–9.0)	All patients
Arrival → CT	–0.8 (–2.5–0.8)	May reflect timing documentation issues
Arrival → MRI	3.8 (1.9–5.9)	All patients

Table 6. Agreement Between CT and MRI for Stroke Subtype

Variable	N	Agreement, n (%)	Disagreement, n (%)	Cohen's kappa (95% CI)
CT vs MRI (n=81)	81	70 (86.4%)	11 (13.6%)	0.664 (0.53–0.80)

Table 7. Summary of Key Associations Between Stroke Type and Radiological/Clinical Variables

Variable	Ischemic Stroke (%)	Hemorrhagic Stroke (%)	p-value	Odds Ratio (95% CI)
CT Normal	70.3	13.5	<0.001	0.07 (0.03–0.16)
CT Hypodensity	58.1	0.0	<0.001	—
CT Hyperdensity	0.0	50.0	<0.001	—
MRI Diffusion restriction	61.5	0.0	<0.001	—
MRI Chronic infarct	69.2	0.0	<0.001	—
MRI Hemorrhage	0.0	100.0	<0.001	—
MRI Edema	69.2	100.0	0.026	—
Atrial Fibrillation	31.8	48.1	0.052	1.97 (1.03–3.76)

Across five time intervals from symptom onset to CT scan, MRI consistently outperformed CT in correctly classifying stroke subtype, with MRI accuracy increasing from 80% (95% CI: 67–91%) to a peak of 89% (95% CI: 79–98%) between 2.5 and 3.5 hours, and remaining above 85% in all later intervals. In contrast, CT accuracy improved from 60% (95% CI: 41–77%) to a maximum of 74% (95% CI: 59–86%) by 4.5 hours, but never matched MRI. Notably, the gap in accuracy between MRI and CT persisted throughout all time points, with MRI maintaining a 12–19 percentage point lead.

Simultaneously, median NIHSS (stroke severity) increased steadily with longer onset-to-CT times, rising from 6.5 (SE 1.0) at 1.5 hours to 12.5 (SE 1.6) at 5.5 hours. This trend suggests that patients imaged later tended to have more severe strokes. Importantly, both CT and MRI accuracy curves plateaued as severity rose, indicating that imaging performance remained robust even in sicker patients, with MRI preserving superior diagnostic yield.

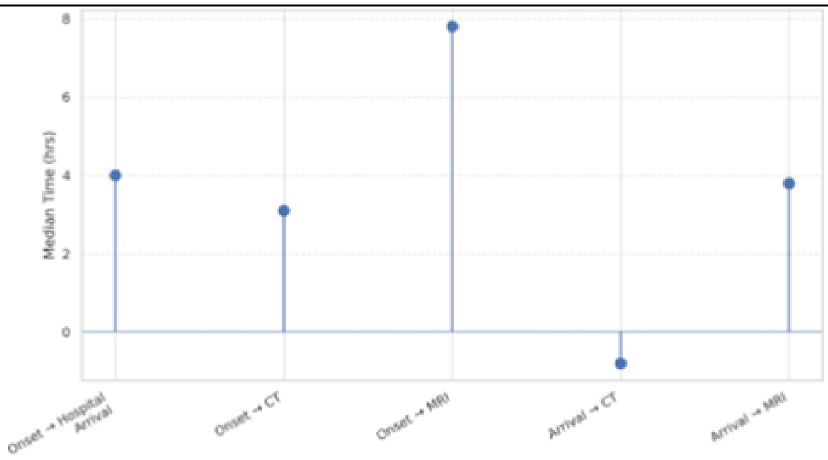

Figure 5: Time Intervals from Onset to Imaging Steps

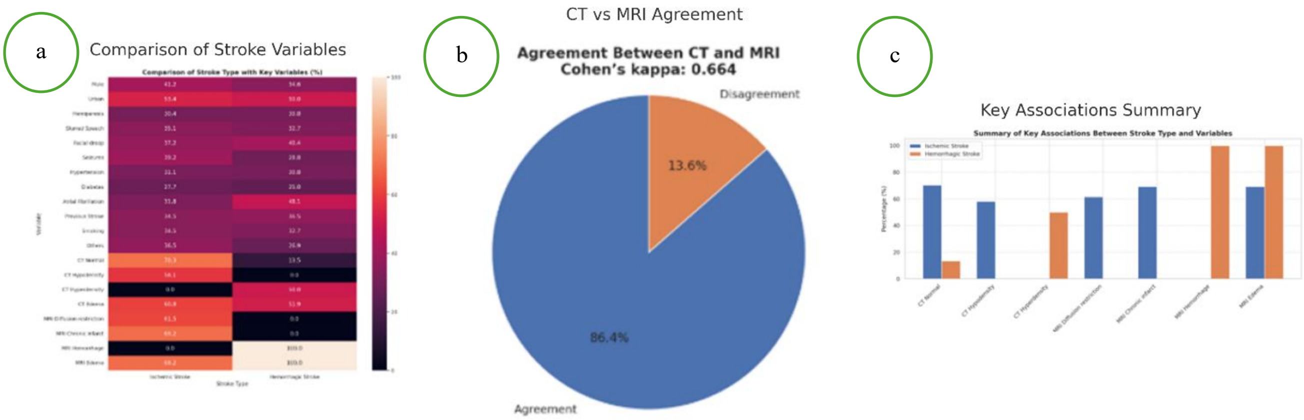

Figure : (a) Comparison of Stroke Variables; (b) CT vs MRI Agreement; (c) Key Associations summary

These findings underscore that MRI is not only more accurate than CT for early subtype classification but also maintains its advantage irrespective of imaging delays and increasing clinical severity. Early imaging—especially with MRI—remains critical for optimal diagnostic precision, supporting prioritization of MRI resources where available, particularly for patients with delayed presentation or high stroke severity.

DISCUSSION

This study provides important insight into the diagnostic performance of CT and MRI for differentiating ischemic and hemorrhagic strokes within an urban tertiary care context in Pakistan, where timely imaging decisions are critically constrained by resource availability. Consistent with prior reports, our findings confirm that CT remains highly reliable for detecting hemorrhagic stroke, evidenced by hyperdensity on CT in 50% of hemorrhagic patients and its complete absence in ischemic stroke cases (22). However, CT's sensitivity for ischemic stroke was limited, with 70.3% of ischemic patients demonstrating normal CT scans despite clinically apparent deficits, reflecting its known limitations in detecting early parenchymal changes (23). These data underscore the inherent challenges clinicians face when interpreting normal CT findings in acute stroke settings and reaffirm the reliance on clinical judgment or adjunctive imaging techniques such as CT perfusion or MRI to guide decision-making, particularly for thrombolysis eligibility (24).

MRI demonstrated a clear advantage over CT for ischemic stroke detection, as expected based on previous evidence supporting diffusion-weighted imaging (DWI) as the gold standard for early ischemia detection (25). In our cohort, MRI showed diffusion restriction in 61.5% of ischemic stroke cases and identified chronic infarct in 69.2%, while hemorrhage on MRI was universally present in hemorrhagic patients and entirely absent in ischemic strokes. These patterns not only reinforce the distinct diagnostic profiles of both modalities but also emphasize MRI's superior sensitivity and specificity in early ischemic detection, which may enhance confidence in clinical decision-making for thrombolytic therapy when available (26).

A novel contribution of this study is the analysis of diagnostic agreement between CT and MRI, where a substantial concordance (Cohen's kappa 0.664) was observed, reflecting robust cross-modality reliability when both tests were performed. While this substantial agreement suggests that CT can serve as a pragmatic first-line diagnostic tool when MRI access is delayed or unavailable, our findings also show that MRI frequently provided critical additional diagnostic clarification, especially among ischemic stroke patients with normal CT scans (27). This reinforces international recommendations advocating CT as the frontline imaging modality for rapid exclusion of hemorrhage, followed by MRI in equivocal cases or where thrombolysis is contemplated beyond the traditional early time window (28). Importantly, our analysis of imaging timelines revealed a median symptom onset to CT time of 3.1 hours and a median symptom onset to MRI time of

7.8 hours, reflecting timely institutional workflows but also illustrating that delays in MRI access persist relative to CT in this setting. Despite these delays, MRI accuracy for subtype classification remained consistently superior to CT across all time intervals, suggesting that MRI retains its diagnostic advantage even when performed later in the acute stroke trajectory (29). Furthermore, the parallel increase in stroke severity with longer imaging delays, reflected by median NIHSS scores rising from 6.5 to 12.5 over time, highlights a clinically relevant trend whereby patients presenting later not only have greater stroke severity but also face additional diagnostic challenges (30). Our figure analysis demonstrated that MRI performance was robust irrespective of increasing stroke severity, supporting its role as a high-yield diagnostic modality in complex or delayed presentations (31).

This study also identified a noteworthy trend toward a higher prevalence of atrial fibrillation in hemorrhagic stroke patients (48.1% versus 31.8%, $p = 0.052$), a finding that differs from traditional paradigms where atrial fibrillation is primarily associated with ischemic embolic strokes (32). One plausible explanation is that patients with atrial fibrillation in our cohort may have been more likely to receive anticoagulants, increasing their risk of anticoagulation-related intracerebral hemorrhage. This observation aligns with emerging literature suggesting that anticoagulation use in patients with atrial fibrillation must be carefully balanced in populations with elevated hemorrhagic risk, particularly in South Asia where hypertension, a common hemorrhage risk factor, is often poorly controlled (33).

While clinical features such as hemiparesis, facial droop, and slurred speech were frequently observed in both stroke types, they did not significantly discriminate between ischemic and hemorrhagic strokes in our analysis. This finding reflects the clinical reality that presenting symptoms are often overlapping and nonspecific, further reinforcing the indispensable role of neuroimaging in stroke subtype classification and treatment planning (34). The lack of significant differences in hypertension, diabetes, smoking, and previous stroke history between groups supports a growing recognition that these common vascular risk factors contribute to overall stroke risk rather than subtype-specific prediction (35).

Our results must be interpreted in light of certain limitations. The retrospective single-center design may limit generalizability beyond tertiary care settings in urban Pakistan, where imaging infrastructure and diagnostic expertise may differ from rural environments. The study's reliance on documentation for timing intervals introduces a potential for recording bias, although this was mitigated by systematic cross-verification with radiology timestamps. Additionally, we did not assess long-term outcomes or incorporate advanced imaging markers such as infarct volume or collateral status, which may further refine diagnostic and prognostic accuracy (36).

Nevertheless, this study adds valuable region-specific empirical data to the global literature, demonstrating the diagnostic contributions of CT and MRI in acute stroke assessment within a resource-constrained healthcare system. Our findings support the continued use of CT as the frontline modality for hemorrhage exclusion due to its speed and availability, while underscoring MRI's superior performance for early ischemic stroke detection and confirming its value when clinical suspicion persists despite a normal CT. The consistent diagnostic advantage of MRI even among patients with delayed presentation and increasing stroke severity provides a compelling rationale for policymakers to expand MRI access and integrate it systematically into stroke pathways where feasible (37).

In conclusion, these findings highlight that an imaging strategy combining rapid initial CT with selective MRI provides the best balance of speed, diagnostic accuracy, and resource utilization for acute stroke care in settings similar to Pakistan. Future research should aim to integrate perfusion imaging and standardized stroke severity scales into diagnostic algorithms, and explore how diagnostic performance translates into clinical outcomes, length of stay, and cost-effectiveness in LMIC contexts (38).

CONCLUSION

This study demonstrates that while computed tomography remains an essential first-line imaging modality for the rapid exclusion of hemorrhagic stroke due to its accessibility and speed, magnetic resonance imaging provides superior sensitivity and specificity for the detection of ischemic stroke, even when performed later in the clinical course. The substantial agreement between CT and MRI underscores their complementary roles but highlights MRI's added diagnostic value, particularly in patients presenting with normal CT scans despite significant neurological deficits. Clinical variables and presenting symptoms, although frequent and overlapping, did not significantly differentiate ischemic from hemorrhagic stroke, reaffirming that imaging remains indispensable for accurate classification. The observed trend toward a higher prevalence of atrial fibrillation in hemorrhagic stroke cases emphasizes the importance of careful anticoagulation management in high-risk populations. The temporal analysis showing increasing stroke severity with longer delays further reinforces the principle that "time is brain" and the need for expedited imaging workflows. Overall, these findings advocate for a pragmatic imaging strategy that prioritizes rapid initial CT, followed by selective MRI where diagnostic uncertainty persists or when clinical suspicion of ischemia is high despite a negative CT, particularly in resource-limited settings. The results provide an evidence base for optimizing acute stroke diagnostic pathways in Pakistan and similar low- and middle-income countries, supporting equitable, timely, and accurate care that can reduce morbidity and improve outcomes in this high-burden disease.

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